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PLANS AND BIDS FOR A PUMPING PLANT "to provide a positive and quick means of emptying the aqueduct siphon under the Harlem River," which forms a portion of the new Croton Aqueduct, will be received until Dec. 17. The plant must have a capacity of 2,500,000 gallons lifted 337 ft. in twelve hours. The apparatus will displace a bailing outfit now provided for use at Shaft No. 25 near 179th St. and Amsterdam Ave. The bottom of the pumping shaft is 424.25 ft. below the engine room floor, but the water is to be discharged at a point 87 ft. below the floor. Bidders must state the power which they propose to provide. The contractor must take apart, remove and store the hoisting engine, cables, buckets and accessories composing the present bailing outfit, with the exception of the sheaves and boilers. He must construct or reconstruct foundations for the new plant. When he has installed the new pumping machinery he must test its capacity by pumping water through a meter to be temporarily provided and set on the existing 48-in. outlet pipe. It may be added that there are two wells at the bottom of this shaft, one of which forms a part of the aqueduct and the other serves as a pump well. The pump well is filled with water to a depth of 337 ft., "while in the adjoining well and aqueduct," the specifications state, "the water is flowing to an elevation of 123 ft. higher than the overflow pipe or the 337 ft." Mr. Wm. B. Hill, M. Am. Soc. C. E., 280 Broadway, New York, is Chief Engineer of the Croton Aqueduct.

A NEW RESERVOIR FAILED AT EAST LIVERPOOL, O., on Oct. 13. The tracks of the Cleveland & Pittsburg Railway were covered with debris for several hundred feet and the plant of the Harker Pottery Co. was damaged by water and mud. The reservoir, as nearly as can be learned, was to have a capacity of 10,000,000 or 12,000,000 gallons, and was being filled for the first time. It was lined with concrete. The break was located at one corner, and was apparently just over a pipe laid through the embankment at that point. The new reservoir adjoined an old one. The reservoir was constructed, according to the local press, under the direction of Mr. Philip Morley, Superintendent of Water-Works.

THE COMPLETION OF THE NEW WATER-WORKS tunnel at Cleveland, O., has been undertaken by the city, with Mr. Geo. H. Benzenberg, M. Am. Soc. C. E., of Milwaukee, as consulting engineer, and Mr. T. H. Murphy, who was on the Milwaukee tunnel work, as resident engineer in charge. The fire at Crib No. 2, on Aug. 14, and the displacement of the steel shaft lining at Crib No. 3, on Aug. 20, were described at length in our issue of Aug. 29. The city rebuilt the burned crib at its own expense and then ordered the contractors to work from Crib No. 2 towards No. 3, while the city, to expedite matters, worked at the other end of this section. The contractors claimed that this action by the city was a violation and cancellation of the contract, although the city disclaimed any such intention. The contractors took their men from the cribs and have done no work for some three weeks. Mr. E. W. Bemis, Superintendent of water-works, informs us that the city hopes to complete the remaining 3,600 ft. of 9-ft. tunnel within a year.

SLOW SAND FILTRATION for a portion of the water supply of Reading, Pa., has been defeated for a second time. A few weeks ago the water board received bids for various systems of filtration. It recommended the acceptance of bids for slow sand filtration, but the city council, by a vote of 18 to 8, has refused to approve the award.

THE GARBAGE REDUCTION WORKS AT BOSTON, Mass., are to be moved from their present site in the Dorchester district to Spectacle Island, in the harbor. The city council has voted to pay the New England Sanitary Product Co. $140,000 for moving the plant and to extend its contract three years, making it expire ten years hence. All this is the result of a long-continued agitation by the residents of the Dorchester section, who claim that the reduction plant is a nuisance.

BIDS FOR THE FINAL DISPOSITION OF ASHES and street sweepings in the city of New York, during 1902, will be received on Nov. 1. There will be one contract for the boroughs of Manhattan and the Bronx and another for the borough of Brooklyn. The specifications for Manhattan and the Bronx provide that the contractor shall receive the refuse on barges at the various city dumps on the water front and dispose of the material in an unobjectionable manner, "not prejudicial to the public health, and the process employed by the contractor is to be not only not noisome in its operations, but also to be effective as to final results." Dumping at sea will not be allowed except with the written permission of the commissioner of street cleaning. Culling of refuse at the water front is prohibited. The contractor must have a plant capable of handling at least 8,000 cu. yds. of ashes and street sweepings in 24 hours. The Brooklyn specifications differ in several particulars from those for Manhattan and the Bronx. The bidders must specify where the city is to deliver the ashes and sweepings "and if any transportation in addition to the carting" by the city "is contemplated by the contractor, plans and specifications of the devices for unloading carts and wagons and the transporting devices which it is proposed to employ must be presented" for approval by the commissioner of street cleaning. Neither the ashes nor the sweepings delivered by the city under the Brooklyn contract may contain more than 10% of other refuse. The chief limitations on final disposal for Brooklyn are that the method shall not be "prejudicial to the public health." The capacity of the plant is not stated, further than a citation of figures for the year 1899, when a total of 900,000 cu. yds. of ashes and sweepings were removed, with a maximum of 4,000 cu. yds. per day. Mr. P. E. Nagle, 13 Park Row, New York city, is commissioner of street cleaning.

THE MOST SERIOUS RAILWAY ACCIDENT of the week was a head-end collision on the Iron Mountain Ry., near De Soto, Mo., on Oct. 18. One person was killed and two seriously hurt. One of the trains, a northbound passenger train, was 3½ hours late, and a fast freight leaving the yards at De Soto before the passenger had arrived, caused the collision.——An unusual accident occurred in a deep cut near Fanwood, N. J., on Oct. 15. Three heavily loaded freight trains and a pusher engine were climbing through the cut together at a rate of about three miles an hour when an air hose on the first train burst and set the brakes. The other engines kept on pushing and as a result nearly half the cars were demolished and two of the engines badly damaged.

A FALL OF ROCK FROM THE ROOF of the New York Rapid Transit Tunnel, at 164th St. and Eleventh Ave., on Oct. 18, killed five men who were working beneath it. The accident occurred in one of the deep tunnel sections of the work. At 167th St. there is a shaft 110 ft. deep, from the bottom of which headings have been turned north and south, keeping at a depth of something over 100 ft. beneath the surface. The fall of rock occurred in the south heading, about 600 ft. from the shaft, where, at the time, a gang of about 20 men were at work. As stated, five of these men were killed. The rock penetrated is full of seams, and has to be carefully watched to prevent accidents, the usual test being to send a man into the heading after each blast to examine and test the hanging rock with a tamping bar. This test had been made as usual just previous to the accident and had failed to show any indication of danger. The contractors for the portion of the tunnel on which the accident occurred were L. B. McCabe & Bros. of New York.

THE CASE AGAINST THE CARTER CONTRACTORS for conspiracy to defraud the Government in the Savannah Harbor work is still delayed through technicalities. The members of the contracting firm were indicted in Georgia two years ago, but have succeeded thus far in defeating every effort to remove them to Georgia for trial. After tedious delays an order for their removal to Georgia was issued in August last by the U. S. District Court in New York; but its execution was delayed by a writ of habeas corpus obtained by the contractors' attorney, who, it may be noted, is the same one that conducted Carter's defence. On Oct. 21 Solicitor-General Richards before the U. S. Supreme Court urged that prompt disposal be made of the case and stated that the testimony adduced shows beyond question that Carter received over $700,000 as his share in the proceeds of the conspiracy, and while Carter has been in prison more than a year and a half, the defendants, who received twice as much, are still at liberty. "The Government," he said, "has spent thousands, and used every effort to bring them to trial, but they have not yet even been brought to the bar and compelled to plead to the indictment found in Georgia two years ago. Their sole fight is for delay. The reason is apparent. Already four of the most important witnesses for the Government have died. Their testimony cannot be replaced. If it is not possible for the Government to put a stop to this policy of delay, a deplorable failure of justice in this case will inevitably result."

THE ENGLISH DESTROYER "COBRA" collapsed in the North Sea on Sept. 18, from causes altogether due to structural weakness, says the court of inquiry ordered to investigate the disaster which cost the lives of about 70 men. She did not touch ground at any time, and no errors were made in her navigation.

THE PACIFIC MAIL STEAMSHIP "SIBERIA" was launched at the yards of the Newport News Shipbuilding Co., Oct. 19. The "Siberia" and the "Korea," her sister ship, are building for the Pacific Mail Steamship Co.'s line between San Francisco and Hong Kong. Each ship will cost, when completed, $2,000,000, and their dimensions are: Length, 572 ft. 4 ins.; beam, 63 ft.; depth, 40 ft.; draft, 27 ft.; displacement, 18,600 tons. Accommodations are furnished for 200 first-class passengers and 1,200 Chinese in the steerage. The ships are designed for a sustained speed of 18 knots an hour, and it is expected that this speed will be exceeded for short periods. They are propelled by two four-cylinder, vertical inverted, direct-acting, quadruple expansion engines, designed to develop 18,000 I. HP. at 86 revolutions a minute.

THE DIRIGIBLE BALLOON CONSTRUCTED by Santos-Dumont succeeded on Oct. 19 in making a trip from St. Cloud to and around the Eiffel Tower, and then back to the starting point in 30 mins. 40¼ secs. The first part of the trip to the tower was with the wind ,and was made in 8 mins. 45 secs., but the return trip was against the wind and required 20 mins. 30 secs. to complete. The remaining 1 min. 40¼ secs. was consumed in descending. The trip was undertaken as the result of a prize of 100,000 francs offered the inventor should he succeed in making the journey in 30 mins. According to the press despatches, the balloon pitched somewhat when going against the wind, and Santos-Dumont, when he descended, said the motor suddenly stopped while the balloon was at a little distance from the tower. He thought he might have to descend, but luckily he succeeded in getting the machine started again. From that time on the motor worked satisfactorily.

A SUBMERGED BELL SIGNAL BUOY is to be established off Egg Rock, Marblehead, in 15 fathoms of water and about 50 ft. below the surface. From a power-house on shore an electric cable will be run out to the bell and connected so as to operate a mechanism actuating the bell tongue or clapper. The theory on which the signal has been constructed is that the sound of the bell will travel further under water than it would through the air, and will thus furnish a more effective fog signal than does the ordinary bell buoy riding on top of the waves.

A SECOND LARGE PURCHASE OF MEADOW LAND near Jersey City and Newark, N. J., has been made. This time 930 acres in Kearney township have been sold to Henry L. Sprague, of 15 Broad St., New York city. The earlier purchase embraced adjoining land to the north in Bergen Co. It is said that the purchase is in the interest of a syndicate, and that the identity and purpose of its members will be announced soon. It is also alleged that the Hackensack Meadow Co., which was recently incorporated, will build dikes, wharves, warehouses and factories, and also spurs connecting with the various railways centering in Jersey City and vicinity.

THE NEW YORK STATE AID ROAD ACT up to Oct. 1, 1901, has already resulted in the completion of 46 miles of improved roadways, besides which 122 miles were under construction on the date named. In addition some eight miles are about to be let, while the county authorities have approved plans and provided money for 134 miles more. When all the roads mentioned have been completed the total mileage built under the Higgble-Armstrong act (Chap. 115, Laws of 1898) will be 310, embracing 106 roads in 23 counties, and costing $2,289,374. Of this sum the State pays one-half. The balance is raised by the county, but 30% of it, or 15% of the total cost, is assessed upon abutting property-owners. The foregoing has been abstracted from "Bulletin No. 3, Improvement of Highways," issued by Mr. Edw. A. Bond, M. Am. Soc. C. E., State Engineer and Surveyor, Albany, N. Y.

THE PERIYAR DAM AND IRRIGATION WORKS, SOUTHERN INDIA.

The Periyar irrigation works, which the British-Indian Government is about bringing to a final completion, rank among the most important engineering works of this character in the world. Briefly summarized, they comprise a dam 173 ft. high above the foundations, built of hydraulic lime concrete; a tunnel 5,704 ft. long and 7½ × 12 ft. in section; a complete system of distributing canals, consisting of a main canal 38 miles long and some 55 miles of branch canals already planned for; and the necessary appurtenances to these main works. The magnitude of these various items will be readily appreciated by engineers and are alone sufficient to warrant a full presentation of the work in Engineering News. Combined with these features there were, however, the unusual conditions that the works had to be built in a wild and uninhabited jungle, at a site where even ordinary highway transportation was lacking, possessing an extremely unhealthy climate, and where even unskilled coolie labor was difficult to secure. Altogether, therefore, it is with particular interest that we present the following account of the Periyar irrigation system prepared from the official record of the work recently published by the Public Works Department of the Madras Government.*

PLAN AND PURPOSE OF THE WORK.

The purpose of the Periyar works is to supply irrigation to the thickly settled but comparatively rainless district of Madura, situated near the extreme southern point of India. This district is bounded on the west by a watershed, beyond which lie the western ghauts, an enormous area of jungle with a large and unfailing yearly rainfall and great quantities of water running to waste. This jungle is uninhabited and uncultivated, and the idea naturally enough occurred that it would be an excellent thing to divert the water running to waste here, to the eastern slope of the watershed where it would be of the utmost benefit to the dense farming population of the Madura district. As long ago as 1808 investigations were made with this object in view, which, however, came to naught. In 1862 the project was again taken up and from this time on it was the subject of intermittent studies, until finally in 1882 a comprehensive plan was outlined by Colonel John Pennycuick, Royal Engineers. It may be stated before going further that both the design and accomplishment of the project have been chiefly due to this engineer.

To understand Col. Pennycuick's plan it should be noted that the main drainage system of the western ghauts is the Periyar River, which rises on the western and southern slopes of the watershed and flows generally westward. Col. Pennycuick proposed to dam a portion of the headwaters of this stream and convey the impounded water by a conduit tunnel through the ridge of the watershed to a distributing canal system on its eastern and northern slope. The map, Fig. 1, shows the portion of the river which it was proposed to dam. Previous projects had successively placed the location of the dam at sites Nos. 1, 2 and 3, with the tunnel passing through the ridge at the head of the Chinna Muliyar valley, but Col. Pennycuick found that by locating the dam further down stream, at site No. 4, a larger reservoir could be secured by a much lower dam, and that a height of 13 ft. could be saved in crossing the ridge. Further details of the general plan will be brought out as the description proceeds. For the purpose of this description the work may be divided into: (1) The construction of the dam; (2) the construction of the tunnel, and (3) the distributing canal system.

CONSTRUCTION OF THE DAM.

The location of the dam being in an uninhabited country utterly devoid of transportation facilities the first problem which had to be met was that of securing and caring for the necessary supplies of labor and materials. Its solution required that laborers must be imported and living quarters prepared and maintained in a jungle for their accommodation; thoroughfares had to be prepared for the transportation of materials across the watershed, and to the site of the dam, and a power development, work shops and other plant had to be constructed on the ground. Each of these items of "preliminary work" will be discussed briefly before proceeding to the work of actual construction on the dam proper.

LABOR.—All the unskilled laborers and the bulk of the skilled laborers were natives. For unskilled labor coolies were employed at first by the day, but afterwards under a piecework system. The reason for the change was that it was found that owing to incompetent and untrustworthy native bosses the "soldiering" was so great by day

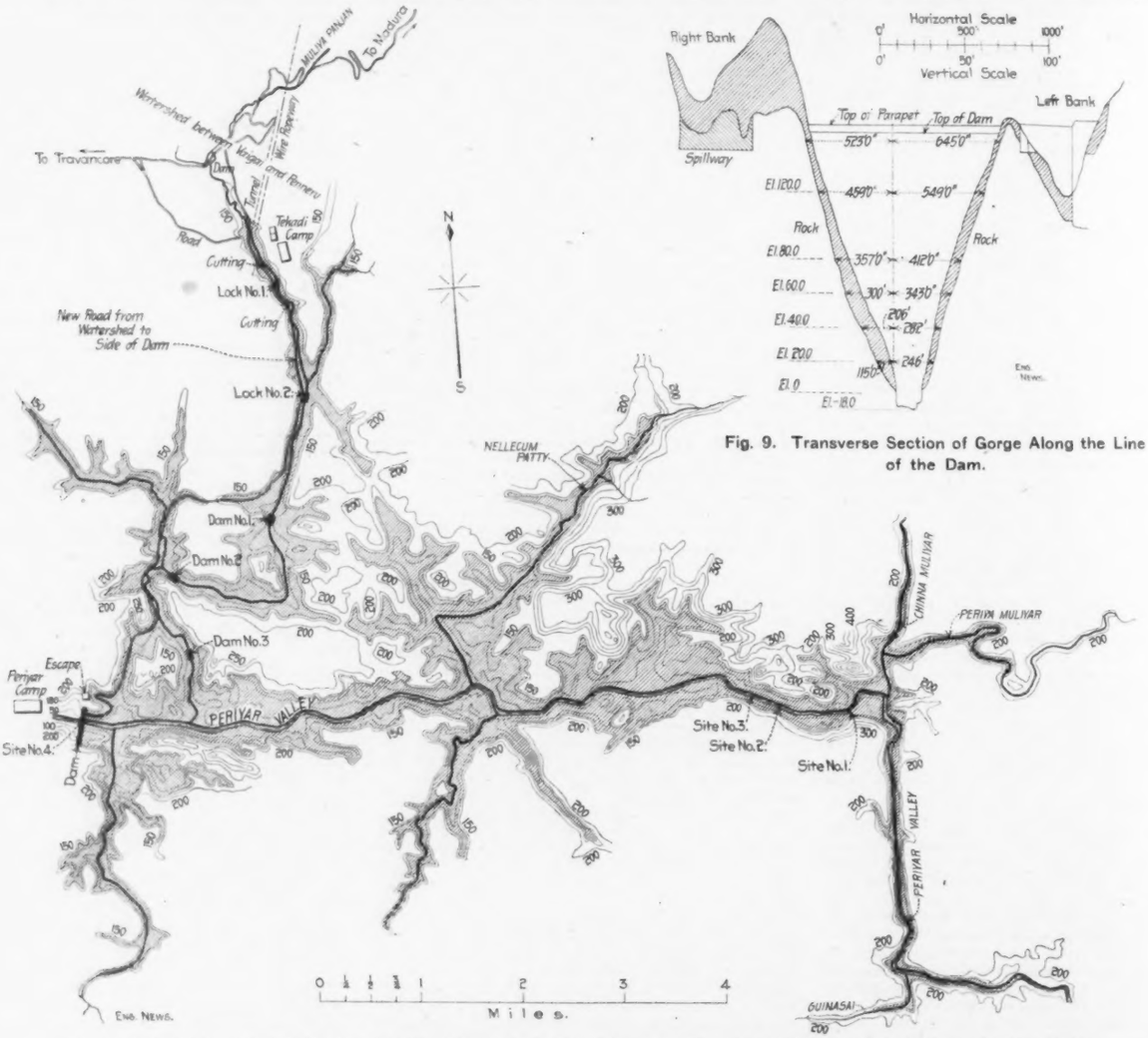

FIG. 1. MAP SHOWING RESERVOIR, MAIN DAM AND DISCHARGE TUNNEL OF PERIYAR IRRIGATION WORKS, INDIA.
Col. John Pennycuick, Royal Engineers, Chief Engineer.

Fig. 9. Transverse Section of Gorge Along the Line of the Dam.

*"History of the Periyar Project," compiled by A. T. Mackenzie, M. Inst. C. E., Executive Engineer, Madras Public Works Department; printed by the Government Press, Madras, India.

labor that the earthwork was costing some 500% more than the estimated cost. The piecework system, when first inaugurated, was received with so much dissatisfaction that the entire force of coolies to a man quit the work. It was persisted in, however, and finally successfully established, if the fact be neglected that the coolies embraced every opportunity to cheat their employers. At the best these laborers were very irregular, owing largely to the fact that the high wages paid them gave them a command of money to which they were unaccustomed, and they improved every opportunity to return to their villages and celebrate.

Among the skilled laborers, the carpenters were Portuguese and they proved excellent workers in all respects. The masons were, however, natives and they proved an unending source of trouble. The rate of pay was necessarily high and any ambitious coolie who could borrow or steal a pair of old boots and a trowel presented himself unblushingly for the "job." Their sole idea was haste and the quality of work turned out by them was such that the most stringent supervision and severe penalties were required. Owing to the vast amount of quarrying a large number of drillers were required. These men worked mostly single-handed, using "jumper" or "churn" drills, and they could only drill vertical holes from 3 to 3½ ft. deep and 1 in. in diameter. They worked well and caused little trouble, except for the fact that they would surreptitiously attempt at every opportunity to drill out old "miss-fire" holes to give them the appearance of new holes and receive pay for them, with a result which successfully disclosed the attempted cheat, even if the coolie did not remain to receive the regular punishment provided for such offenses. As regards machinists it is stated that these gave perhaps more trouble than all the rest together; it was found impossible at any reasonable wages to get together a staff at once capable and reliable.

Besides the faults of the workmen themselves there was the additional disturbing influence of disease. The site of the dam is an extremely unhealthful location and there were serious outbreaks of fever, cholera, rheumatism, dysentery, and pulmonary complaints due to the cold, dampness and malaria and to the carelessness of the natives in regard to sanitation. Every reasonable provision was made to prevent disease and to care for sick persons, but despite all this the death rate varied from 2 to 19 per 1,000 per month.

MATERIALS.—The conditions of the work, for reasons which will be evident from what has been said, prompted the use as far as possible of local structural materials in building the dam. The local rock was largely useless for stone masonry, but crushed it provided an excellent material for concrete. Cement was available only by importation from Europe, but limestone from which excellent lime could be burned could be had just across the ridge of the watershed on the route of the main distribution canal. It was decided, therefore, to build the dam of hydraulic lime concrete, using the local broken stone and bringing the limestone from across the ridge of the watershed and burning it in kilns located near the dam site. Both intermittent kilns of clay and larger continuous kilns of stone in clay with an outside casing of stone in mortar were used for lime burning. The lime was slacked on a prepared surface close to the kilns as soon as it was drawn and then stored in thatched sheds and used generally within between one and three months after burning. The lime was used with surki and sand to make mortar and also when combined with broken stone and sand to make concrete.

The surki was made in the form of tiles from suitable local soils, and underburned in small clay kilns. Crushing the burned tiles fitted the material for mortar making. The sand was dredged from the bed of the Periyar River. Three parts by volume of sand, two parts of surki and one part of lime composed the mortar. This mortar was mixed in pan mills or in country bullock mills, the former method giving the better appearing and working although apparently no stronger product. The process was as follows: The pan or trench having been cleaned the surki in bricks or tiles was first thrown in and partly broken up, a little water being then added and the mill revolved until the powder was fairly fine. Lime was then added by degrees and more water until a rather sloppy mortar was formed and thoroughly mixed and ground. Sand was then gradually poured in dry, a little water being occasionally added when the friction became too great for the engine, until the whole was thoroughly mixed and of the proper plasticity. This mortar mixed with stone broken to pass a 2½-in. ring, composed the concrete for the main dam.

The fuel used was wood cut from the local forest. The quantity required was large, since there were the lime kilns to be supplied with charcoal, and three steamers, a steam tunneling plant and numerous boilers and portable engines to be supplied with firewood.

MECHANICAL PLANT.—The character and extent of the permanent working plant is quite clearly shown by Fig. 2. Practically the only portion of this plant which requires particular description is the main workshed. This shed was supplied with power by a 180-HP. turbine working under a 25-ft. head of water, and contained the rock crushers, lime and surki disintegrators and concrete mixing machinery. The mixed concrete after being conveyed to the upper story of the building was taken to the work by an endless rope cableway running at a speed of 4 miles per hour and having a capacity of 200 tons every ten hours. This ropeway was operated like the other machinery from the turbine. Besides the concrete making machinery the building also contained a water supply pump, a circular sawmill and other machinery.

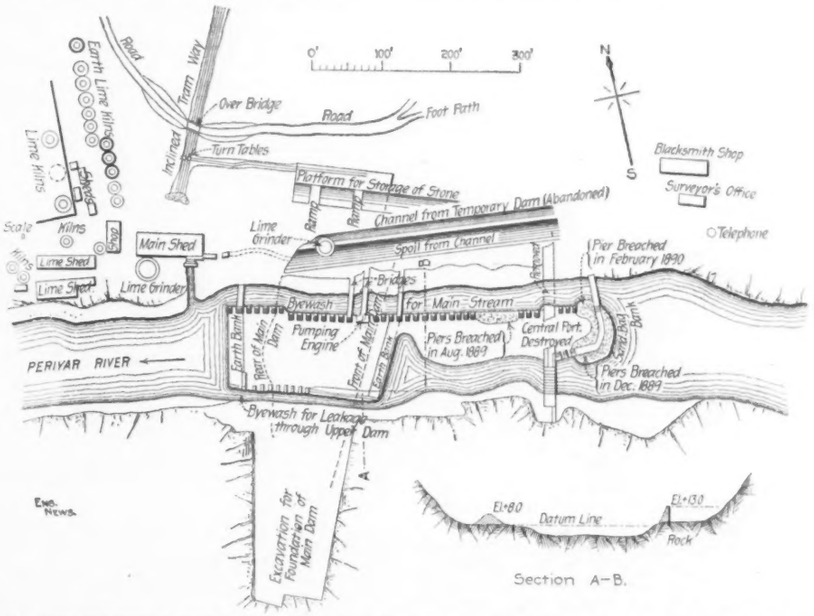

FIG. 2. MAP SHOWING THE LOCATION OF THE PLANT AND WORKS AT THE MAIN DAM SITE.

TRANSPORTATION ROUTES.—To bring in the limestone for lime making and other construction material from the Madura side of the watershed a cableway was constructed up the slope to the entrance of the tunnel as indicated in Fig. 1. From this point both a canal and a rough cart road were constructed to the site of the dam, but the canal was the principal means of transportation employed. It was intended at first to build this canal with locks, but after Locks Nos. 1 and 2, Fig. 1, had been partly built it was decided that their cost was so great and their care and maintenance so troublesome that it would be cheaper on the whole to build dams and transship the cargos at each dam. It was found that three dams would replace the eight locks originally planned. The work of dam building proved very onerous. Each dam entailed a separate camp in the jungle and separate superintendence. During the fever months nothing could be done, and at the best the laborers had to endure bad lodging, bad water, difficulties in obtaining a supply of food and the terrors of wild beasts. That the last affliction may not be passed by as imaginary it may be noted that elephants had constantly to be driven off with tom-toms and fire brands and occasionally a prowling tiger would carry off a careless coolie. These things, as Mr. Mackenzie somewhat naively remarks, made laborers "most reluctant to be employed here." The canal began to be used in 1891, although accidents to the dams interrupted operations from time to time thereafter until 1895, when the water had been backed up sufficiently by the construction of the main dam to make natural navigation possible.

As previously noted, the cargoes had to be transshipped at each dam. The limestone, which was almost the only article carried, was loaded in opening boxes which were first lifted by stationary cranes mounted on the dams, and then placed on frames mounted on wheels which were run on rails laid on piers behind the dam to chutes. The boxes being opened the material ran down the chutes into similar boxes arranged in a boat waiting below. The chutes were swung on pivots to allow for variations in the depth of the water. The boats were flat-bottomed, of wood, generally 40 ft. long, 10 ft. wide and 3 ft. deep, with a free board of about 8 ins. when fully loaded. They were originally square ended, but were afterwards all fitted with bows.

The ropeway up the eastern slope of the watershed was 16,610 ft. long; it was carried on posts spaced about 300 ft. apart and was operated by a 60-HP. turbine working under a head of 179 ft. In stretching the rope the sag allowed for between posts was span 2 ÷ 26,000. The first rope used was Bullivant's steel wire rope, Bullivant's lay, the circumference being 2½ ins. The second rope was of the same size, but Lang's lay. The rope traveled and the buckets were attached to it by Carrington's runners. The weight of each bucket, etc., was 74.5 lbs., and its capacity was 1⅞ cu. ft. of limestone and 1 cu. ft. of surki bricks. The running speed of the rope varied from 2½ to 3 miles per hour. The total difference in height between the terminal stations was 1,250 ft., made up as follows:

Station E to Station C	8,350 ft.	: lift.	1,100 ft.
" C " " B	2,660 "	"	350 "
" B " " A	5,660 "	drop.	200 "

Station A was the one at the tunnel entrance. The quantity of material carried per working day averaged 40 tons. As the working day was about 7 hours actual running of the cable, the hourly capacity of the cable was a little less than 6 tons.

MAIN DAM.—With the preceding brief description of the preliminary work in mind, the actual construction of the dam proper can be taken up understandingly. As previously stated, the dam

was designed to be built of concrete, and was planned to rise 155 ft. above the bed of the river. Fig. 3 is a transverse section of the dam as built. Before proceeding further it will be interesting to establish in the mind the position in respect to its dimensions which this dam occupies in relation to other high masonry dams of the world. For this comparison we have selected only those dams which are 150 ft. or over in height above the foundation bed, and the figures have been obtained in each case from "The Design and Construction of Dams," by Mr. Edward Wegmann, M.

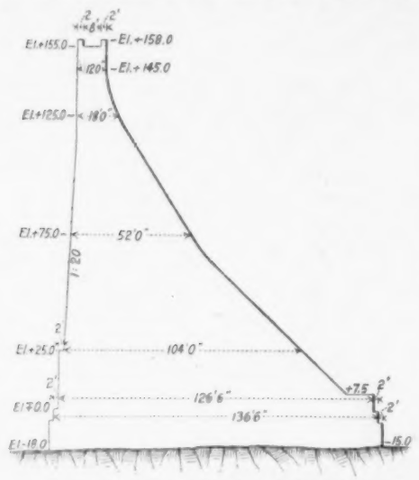

Fig. 3. Transverse Section of Periyar Dam.

Am. Soc. C. E. Table I. gives the comparative figures.

The bed of the river at the site of the Periyar dam is of rock, sloping very gently for a short distance on each flank and then dropping suddenly, in some places vertically, toward the deep channel in the center of the bed. This deep channel was from 50 ft. to 80 ft. wide, and from 10 ft. to 18 ft. below datum, Fig. 4. The maximum flood level is about 20 ft. above datum, but the highest flood level reached during construction was 15 ft. above datum. The existence of this chasm in the river bed added greatly to the difficulty and expense of building the foundations, since, although it gradually narrows both above and below the site of the dam and finally disappears a short distance away in both directions, the nature of the banks prevented any material deviation from the adopted site. When the original designs were prepared the existence of this chasm was not known, and the bed was supposed to be a tolerably smooth rock with its greatest depth not more than 4 ft. below datum. On this supposition it was planned to construct a temporary dam a short distance above the main dam to a height of 30 ft. above datum, and a similar dam 10 ft. high below the main dam, and to lay the river bed dry between these two temporary dams for the construction of the foundations of the main dam. The object of making the upper dam 30 ft. high above datum was to secure as soon as possible a head of water for operating the power plant. The presence of the chasm made it necessary to modify this plan. The general plan, Fig. 2, should be studied in following the description of the plan actually adopted which follows.

Owing to the presence of the chasm it was decided to build the upper temporary dam about 200 ft. higher up the river, where the chasm was much narrower, and to lead the ordinary river discharge around the main dam by a channel cut in the earth of the right bank. The flank portions of the dam, which were in no great depth of water, were put in with no serious difficulty, although with frequent interruptions by floods. To obtain a foundation for the central portion of the dam it was determined to fill the central chasm with dry stone up to water level and to build upon the base thus formed. When the flank portions had reached a height of 13 ft. above datum, it was the plan to stop work on them and to carry the central portion up to 20 ft. above datum and afterwards to keep the central portion well above the flanks so that floods might go over the latter and the rubble base of the central portion not be disturbed by falling water. This plan had been carried out to the extent that the flank portions of the dam had reached their projected elevation of 13 ft. above datum, and the central portion had been carried up to 10 ft. above datum when an unexpected flood occurred and swept away the green masonry of the central portion down to the base of rubble stones.

TABLE I.—Showing Principal Dimensions of Periyar Dam as Compared with those of Other Masonry Dams Over 150 ft. in Total Height.

Name and location.	Depth of water, ft.	Height above base ft.	Thickness in feet. Top.	Thickness in feet. Base.	Area of profile, sq. ft.	Length in feet. Top.	Length in feet. Base.	Material.
New Croton, New York, U. S.	150	219	18	200	28,400	2,240	...	Stone.
Periyar, India	155	176	12	138.5	10,772	1,200	215	Concrete.
Furens, France	164	170.6	9.91	161	15,712	328	30	Stone.
Villar, Spain	162.3	170.33	14.75	154.5	11,596	546	...	Stone.
San Mateo, California, U. S.	...	170	20	176	16,000	700	...	Concrete.
Puentes, Spain	153.54	164.24	35.73	144.29	16,349	925	70	Stone.
Tache, France	...	161.43	.....	.....	.....	...	..	Stone.
Ban, France	137.9	156.82	16.40	126.08	6,780	...	...	Stone.
Gillippe, Belgium	147.64	154.2	49.22	216.5	18,708	771	260	Stone.

To rebuild the dam on the original plan was impossible without a delay of an entire season, so another plan was worked out which would save this delay. The first step was to build a row of masonry piers (Fig. 2) as close as possible to the right edge of the deep chasm extending from the right flank of the temporary dam to a point below the downstream or dry face of the main dam. These piers were 6 ft. apart, 5 ft. wide and 3 ft. thick at the top, which was at elevation 13 ft. above datum, with their rear faces stepped 1 ft. horizontal for 2 ft. vertical. The next step was to remove the portion of the right flank of the temporary dam which was enclosed between the line of piers and the right bank. This being done, the row of piers was continued upstream to a point where the central chasm was still narrower and shallower, then turned across stream around the chasm and down its left edge until the masonry of the left flank of the original temporary dam was encountered. By completing the masonry of the left flank of the temporary dam and closing the spaces between the piers by shutters it will be seen that the river bed above the site of the main dam would be laid dry, so long as the channel on the right bank was sufficient to carry the discharge of the river.

It was reasonably anticipated, however, that there would be some leakage through the shutters, and that in order to keep the foundation dry enough for good work it would be necessary to enclose the immediate site of the main dam with cofferdams above and below it. These dams were formed of wooden trestles carrying two rows of sheet piling, with a filling of earth. Fig. 5 is a transverse section of one of these cofferdams. The trestles were built on shore in lengths of about 30 ft. Batter posts of lengths suitable to the depth of water were set up at distances of 5 ft apart in the line of the dam, as shown at A A. Each pair of batter posts was braced together transversely, as shown, at intervals of 10 ft. vertically, the frames or bents thus formed were connected longitudinally of the dam by double waling timbers. Round timbers having a maximum diameter of 8 ins. were used in constructing the trestles.

Each section of trestle was built for a certain position in the dam, the batter posts being cut to the exact lengths at the bottom to fit the irregularities of the profile of that portion of the river bed covered by the section. When completed each section was towed into position and sunk by lashing boulders to the batter posts. After being sunk a row of oblique sheet piling was driven on each side between the double waling pieces as guides. As soon as all the trestles constituting the dam had been sunk as described, work was begun filling them with earth.

Referring first to the filling of the upstream dam: It was found that the leakage through the shutters amounted to from 25 to 30 cu. ft. per second, which caused a current in the stream to be shut off by the cofferdam. To shut off this current from the interior of the cofferdam various devices were resorted to. Bamboo mats were nailed onto the sheet piling to cover the interstices; sand-bags were sunk on the upstream toe to fill the crevices between the bottoms of the piles and the rock bottom, and the trestles were divided transversely by partitions of sheet piling driven against the transverse bracing. The filling was carried on from each shore toward the middle of the dam, and it was effected without any trouble except the waste due to the floating away of the earth until the center portion of the dam was reached. The leakage had, of course, concentrated

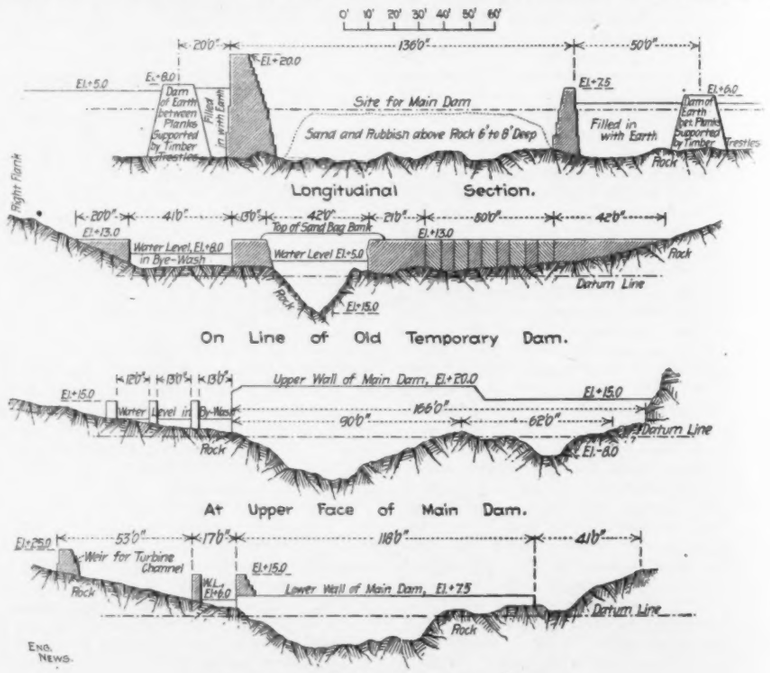

FIG. 4. SECTIONS OF MAIN AND TEMPORARY DAMS.

at this point, and the velocity of the current was considerable. This gap was filled in again and again only to open up each time. Finally the gap was divided into numerous small sections by vertical planking, and these sections were filled one at a time with earth filled with bundles of grass. This method proved successful, and the dam was finally closed.

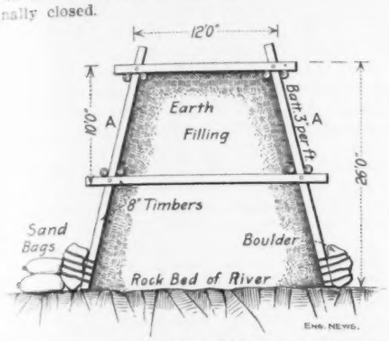

Fig. 5. Transverse Section of Upstream Cofferdam.

The downstream cofferdam was built in an exactly similar manner to the upstream dam just described, but with less difficulty, although considerable of the filling was also washed away here. It was calculated that the amount of earth dumped into the dams was more than 30 times the actual cubical contents of the dams, and in fact when the space inclosed by the two cofferdams had been laid dry it was found to be covered with mud to a depth of from 6 ft. to 8 ft. from the earth which had floated away from between the sheet piling. The dams, even when finished, had to be constantly watched, and an emergency gang with a large quantity of earth was kept ready day and night to repair the cavities that constantly occurred. The working methods of this gang, which was composed of coolies, were curious. A ring of the coolies would form around a cavity pressing close leg to leg, and almost excluding, or at least breaking the rush of water. They were then buried up to their waists in earth by their comrades and pulled out by main force, when the operation was immediately repeated, until bit by bit the breach was healed. This work was cold and disagreeable, and the men had to be assisted and encouraged in every possible way. One of the encouragements which proved most efficacious was liberal supplies of arrack, the national tipple of the natives, having about the strength of rum. In this connection Mr. Mackenzie remarks that "had it not been for the medicinal virtues or arrack it is difficult to see how the Periyar dam would ever have been built."

To resume the narrative, hardly had the cofferdams been completed and the pumping plant installed ready to lay dry the space between them when a flood occurred which set all the previous hard work of constructing the upstream cofferdam at naught. Two of the piers in the portion crossing the river above the old temporary dam were destroyed; the upstream cofferdam was entirely swept away, and the downstream cofferdam was considerably injured. The flood occurred on Dec. 17, 1889, and it was not until Jan. 12, 1890, that the repairs of the damage could be begun. The opening left by the broken piers was filled with sand bags and the cofferdams were rebuilt after the same methods which had been used in the original construction.

By the time the cofferdams had been completed for the second time, the working season was so far advanced that it was impossible in the time available to get in the foundation over the whole area of the dam, even up to normal water level, and it was, therefore, determined to construct only the front and rear portions or walls up to such a level as would be safe from submergence by moderate floods. The longitudinal sections, Fig. 4, explains the plan. The upstream wall was the first to be constructed. The best method of procedure would have been to begin the masonry at the lowest point of the foundation bed, but this, of course, necessitated waiting until the entire foundation bed had been laid dry and cleaned, and haste was too urgent to allow of this delay. Work carried out in a series of successive short lengths from each side, the difficulties from sliding and leakage increasing as the two ends approached and becoming acute as the time for the final junction came. This was successfully made, however, and the work proceeded without any unusual incidents until the wall had been completed to about 7 ft. above datum, except for 40 ft. at the middle, which was 6 or 7 ft. lower. Meanwhile the downstream wall, built exactly like the upstream wall, had been completed to its designed elevation of 7½ ft. above datum, Fig. 4. At this stage of the work a flood swept out one of the masonry piers in the upstream diversion dam, topped the upstream cofferdam and upstream wall at the center, swept off the green top courses of the downstream wall and breached the downstream cofferdam. By the end of the season this damage had been repaired and the upstream wall had been carried to 20 ft. above datum. The different sections, Fig. 4, show the exact condition of the work at this time.

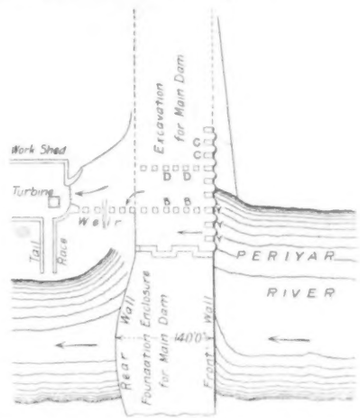

Fig. 6. Sketch Plan Showing Method of Diverting the River Around the Main Dam During Construction.

The walls which have been described were not benched into the foundation rock, as the necessity for haste was too great, but the rough surface of the rock was carefully cleaned and flooded with Portland cement to form a bed for the concrete. Portland cement concrete was used for the lower 2 ft. of the walls throughout their width, and for the front 2 ft. throughout their height. The remainder of the concrete was made with lime.

The next step in the work was to fill the space between the upstream and downsteam walls of the dam. The enclosure was first pumped out, cleared

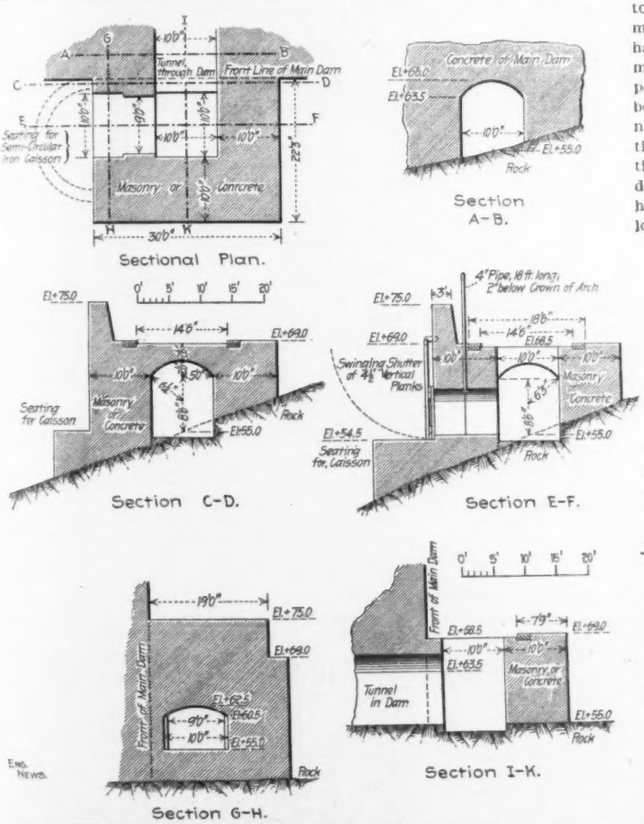

FIG. 7. MASONRY DETAILS OF WASTE CULVERT THROUGH MAIN DAM.

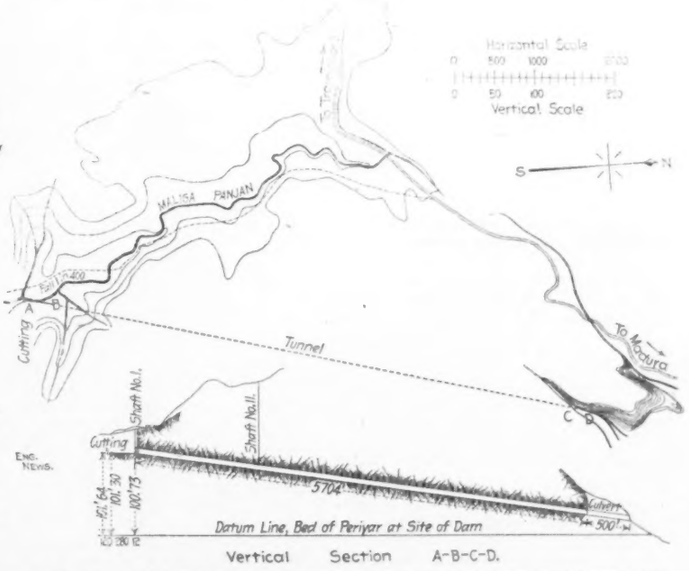

FIG. 10. PLAN AND PROFILE OF TUNNEL THROUGH THE WATERSHED.

of some 80,000 cu. yds. of mud, and the bed rock laid bare. The bed rock was found to be exceedingly rough, and to slope in the reverse way to the fall of the river, so that no benching was necessary. The leakage through the walls had then to be suppressed. This was done by building low rubble masonry walls about 3 ft. behind the main walls, pumping out the water and depositing 6-ft. seals of cement concrete in the spaces. The filling with concrete then began and continued steadily, except for interruptions by floods during the successive working seasons until the dam was completed in October, 1895.

The preliminary arrangement for handling the normal stream discharge has already been described and is shown clearly by the general plan, Fig. 2. It is evident, however, that as the masonry of the main dam rose above the highest level of these original diversion channels, and the flanks were extended inshore, these diversion channels had to be abandoned, since they would be flooded by the dammed water. In his original plan, Col. Pennycuick had proposed to pass the discharge through the main dam by two low-level tunnels which were afterwards to be walled up. When the time came to build these tunnels the Inspector General of Irrigation raised strong objections to the plan, over which there was considerable controversy, but which finally resulted in a temporary abandonment of the original plan. Until the dam reached a height of 60 ft. above datum the water was diverted around its right flank. The method of doing this was as follows:

Taking the foundation enclosure, Fig. 5, as a start, the river was already raised and diverted through the vents between the piers Y, Y, etc. Similar piers A, A, were then built in the line of the upstream face of the dam, leaving vents with floors at a higher level. These piers were then connected with the line of the downstream face of the dam by a line of piers B, B, etc., with grooves into which planks could be inserted to close the vents. The height of these piers, B, B, was so calculated that when the original by-wash Y, Y, was closed and the river was turned through the vents A, A, the ordinary discharge of the river and small freshets should not top the piers B, B, etc. When the foundation enclosure reached a level equal to the piers B, B, the upstream wall of the dam was raised somewhat higher. The original by-wash, Y, Y, was then closed, the water rose and the river began to run to the right of piers, B, B, through the vents A, A. The space between the piers B, B, and the foundation enclosure was then rapidly brought up to the level of the work already built and was then included and the whole went on together. New piers, C, C, and D, D, were then built, and as soon as the body of the dam reached a sufficient height the river was raised and diverted through vents C, C, the space between piers D, D, and piers B, B, was brought up to the level of the rest of the work, etc. By successive repetitions of this process the dam was raised to elevation 60 ft. above datum.

This method had numerous disadvantages. Mr. Mackenzie states that, "the cost, the damage, the innumerable inconveniences may be said to have delayed the completion of the work a full year and added to the expense a sum variously estimated at from 1 to 4 lakhs of rupees" ($40,000 to $160,000). Its drawbacks were indeed so intolerable that at elevation 60 ft. above datum the method was abandoned and the water was thereafter passed by a tunnel or culvert through the dam. The general construction of this waste culvert or tunnel is shown by Figs. 7 and 8.

The tunnel was 10 ft. wide and 8½ ft. high to the springing lines of the roof arch, which had a radius of 6½ ft., and a rise of 2½ ft. The center of the tunnel at its entrance at the upstream face of the dam was at elevation 60 ft. above datum. At the discharge end the tunnel terminates in a discharge chamber 10 ft. wide in the direction of the line of the dam, and 12¼ ft. long, surrounded by a wall 10 ft. thick on three sides, the fourth side being the dam itself. This surrounding wall has its crest at 74 ft. above datum, thus leaving the chamber open at the top. A secondary vent was also provided in one of the side walls, as shown by the drawings. As explained by Col. Pennycuick, this vent "is to serve for the passage of water while the lake is rising to the level at which it can discharge freely through the tunnel (77 or 78 ft. above datum); and at the end of the season it will be permanently built up from behind an iron semicircular shutter." This same gentleman also describes the method of regulating the discharge through the tunnel as follows:

> The top of the chamber at the mouth is closed by a plate of cast iron 14 ft. square with an opening 10 ft. in diameter. This plate fits into a recess in the top of the masonry 14½ ft. square, so as to leave a space of 3 ins. all round between the side of the recess and the side flanges of the plate, to be packed in with neat cement. When the vent in the side wall of the chamber is closed the only route by which the water of the lake can find access to the tunnel will be through the circular opening in the covering plate. At a distance of 4½ ft. above the covering plate is fixed a horizontal circular plate. This plate whose outside diameter is the same as that of the opening of the lower plate is supported by 24 uprights of 40-lb. rails imbedded in the floor of the chamber with sockets at top and bottom, and bed plates under the bottom sockets. The circumferential space between the top and bottom plates is closed by a wrought-iron cylinder of sufficient size to move easily over the outer flange of the top plate, to be lifted by a winding platform, and kept in position horizontally by guides. It is evident that as the water has free access all round the cylinder it will be in complete equilibrium and its own weight will be the only resistance to be overcome in lifting it. The admission of water to the tunnel can thus be properly regulated. The discharge through the tunnel is to be limited to 12,000 cu. ft. per second, and as long as the discharge of the river does not exceed this amount the surface of the lake can be maintained constantly at any level that may be desired. When this discharge is exceeded the water level must rise until it reaches the vents in the left bank extension.

With the completion of the tunnel all trouble respecting the disposal of the discharge ceased. At the end of its usefulness the tunnel was closed with rubble masonry, without any serious difficulty.

SPILLWAY.—It will be seen from the cross-section of the Periyar valley at the site of the dam, Fig. 9, that the main river gorge was paralleled on each side by a gulley separated from it by a ridge. On the supposition that rock would be found a short distance below the surface, it was planned that these gullies should be utilized for the construction of two spillways. It was found after excavation had been begun, however, that the bed rock on the left bank, instead of conforming to the saddle of the gulley, dipped to so great a depth below the left bank of the gulley that it was out of the question to seek for a rock foundation for this end of the spillway. After careful consideration it was decided, therefore, to dam the left bank gulley permanently by a concrete structure similar to the main dam, and to construct but one spillway located on the right bank of the stream. This right bank spillway was a rectangular channel excavated in the bed rock; its bottom was 14 ft. below the parapet of the main dam, and was 420 ft. long.

GENERAL REMARKS.—The principal features of the main dam construction have been described in the preceding paragraphs quite fully, but there remains a few minor phases of the work to be touched upon in conclusion. It has been stated that the main dam was composed of concrete. To prevent leakage, however, the upstream face of the concrete was protected by a substantial wall of rubble stone masonry. This protection served its purpose very well; the leakage through the dam running from one-seventh to one-third a cubic foot per second, according to the level of the lake water, which is of course a quite insignificant amount. To quote Mr. Mackenzie:

> This closes the account of the construction of the Periyar Dam, a work unique in the history of engineering—built amidst unprecedented difficulties across a turbulent river whose highest flood discharge exceeded that of the Thames at Windsor 15 times, and was equal to half the average flow of Niagara; impounding a lake covering more than 8,000 acres, and with a maximum possible depth of 176 ft.

TUNNEL THROUGH THE WATERSHED.

The passage through the watershed may be considered as including: (1) An open cutting or approach 5,342 ft. long on the south side; (2) a tunnel 5,704 ft. long; and (3) an open cutting 500 ft. long on the north side. Fig. 10 is a longitudinal profile and part plan of the tunnel line.

The cutting on the south side, which was known as the watershed cutting, consisted of 3,000 ft. on the level, with its bottom at 115 ft. above datum, and of 2,342 ft. with a fall of 1 in 320, the bottom width being 21 ft. throughout, the sides vertical in rock and with slopes of 1½ to 1 in earth. It was a straightforward but tedious piece of work, the principal trouble experienced being with the Mulya Panjan, whose course crossed the line at several points, and had to be trained and diverted, but which occasionally broke in and deposited a good deal of silt. As each section of the cutting was finished, working northward, it was included in the canal, which thus eventually reached the tunnel entrance, which was also the terminal of the wire ropeway up the Madura slope of the watershed. The total amount of excavation was 2,217,120 cu. ft. of earth, and 633,731 cu ft. of rock, and it was all done by hand.

The other cutting, 500 ft. in length, from 0 to 21 ft. in depth, was also 21 ft. wide on the bottom and had a fall of 1 in 250 northward. The excavation was almost entirely in rock, of which about 158,095 cu. ft. were removed. This cutting was completed before commencing work on the tunnel.

The tunnel proper, as already stated, has a section 12 × 7½ ft., and a descending grade north of

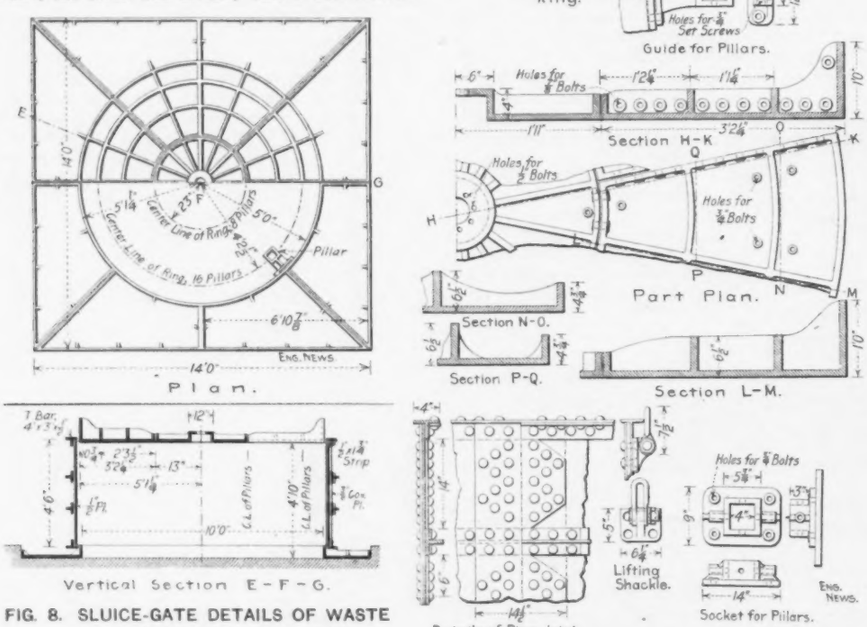

FIG. 8. SLUICE-GATE DETAILS OF WASTE CULVERT THROUGH MAIN DAM.

1 in 75. The material penetrated was a tough granite which drilled hard but blasted well. It was at first designed to drive the tunnel entirely from the north portal, so as to have the advantage of natural drainage, and the main power plant was located here, but afterwards a shaft was sunk at a point 4,146 ft. from the north portal, and excavation prosecuted in both directions from its bottom as well as from the north portal. A secondary power plant was of course required at this shaft.

Briefly described, the main power plant at the north portal consisted of a 50-HP. turbine working under a head of water of 157½ ft. The water was secured by damming the run-off of a small swamp near the ridge of the watershed, and was conveyed to the penstock leading to the turbine by means of an open channel conduit and wooden flume built on piles over intersecting ravines. The compressors consisted of two 16-in. double-acting cylinders fitted with inlet and outlet valves at each end, with pistons of 24-in. stroke driven off two cranks located at an angle of 90° on the same shaft. The pulley was very large and heavy, so as to act as a flywheel, and was driven by spur gearing by means of a countershaft with a belt from the turbine shaft. The cylinders were water-jacketed. The air was discharged into two receivers at a pressure of 30 lbs. per sq. in. From the receivers the compressed air was taken to the working face in 4-in. wrought-iron flanged pipe.

The air was delivered to the drills by means of hose leading off the main air pipe. The drills were first mounted on carriages, but this method was abandoned for column mountings. They varied in size from 2½ ins. downward. About 45 holes were drilled for each length of the full section removed, and were fired in three blasts using blasting gelatine. The spoil was removed in ½-cu. yd. cars running on a 2½-ft. gage track laid on the tunnel bottom. Ventilation was supplied by an exhaust fan having a capacity of 1,000 cu. ft. of air per minute, which was operated by a 6-HP. turbine.

The shaft, noted on the profile Fig. 10 as shaft No. II., was 14 ft. × 7 ft. in lateral dimensions and 109 ft. deep. The power plant used here consisted of three 15-HP. boilers, a horizontal engine and compressor, a 3½-in. rock-boring machine, and a pumping plant. Later on the plant was augmented by a number of portable boilers. Work was begun on the tunnel in November, 1889, and excavation was completed in October, 1894.

HEAD SLUICE GATES.—The sluice gates at the head of the tunnel as originally designed were unsuccessful, and will be abandoned, but a brief explanation of their design is necessary in order to make the construction of the new gates clearly understood. Briefly stated, the tunnel at the head, after running straight a few feet, was divided as shown by the sketch, Fig. 11, into two semicircular arms which met in a sluice chamber, from which the tunnel proper continues in a single straight passageway. At the lower ends of each of the two arms were two vents, one above the other, the upper vents being for the normal discharge, and the lower vents for use in case the upper vents should be closed for repairs. The shutters for the two upper vents were connected so as to be operated simultaneously, and the shutters for the lower vents were operated separately. For various reasons which it would require too much space to make clear, the operation of these shutters proved impracticable and they will be abandoned, as previously stated.

The head sluice construction which will replace that abandoned is shown in considerable detail by Fig. 11. As will be seen, it consists of a Stoney gate closing an opening 12 ft. 9 ins. high and 9 ft. 6 ins. wide, and protected by a screen on the upstream side. The general details of the gate and its appurtenances are so fully shown by the drawings that they need not be explained further here.

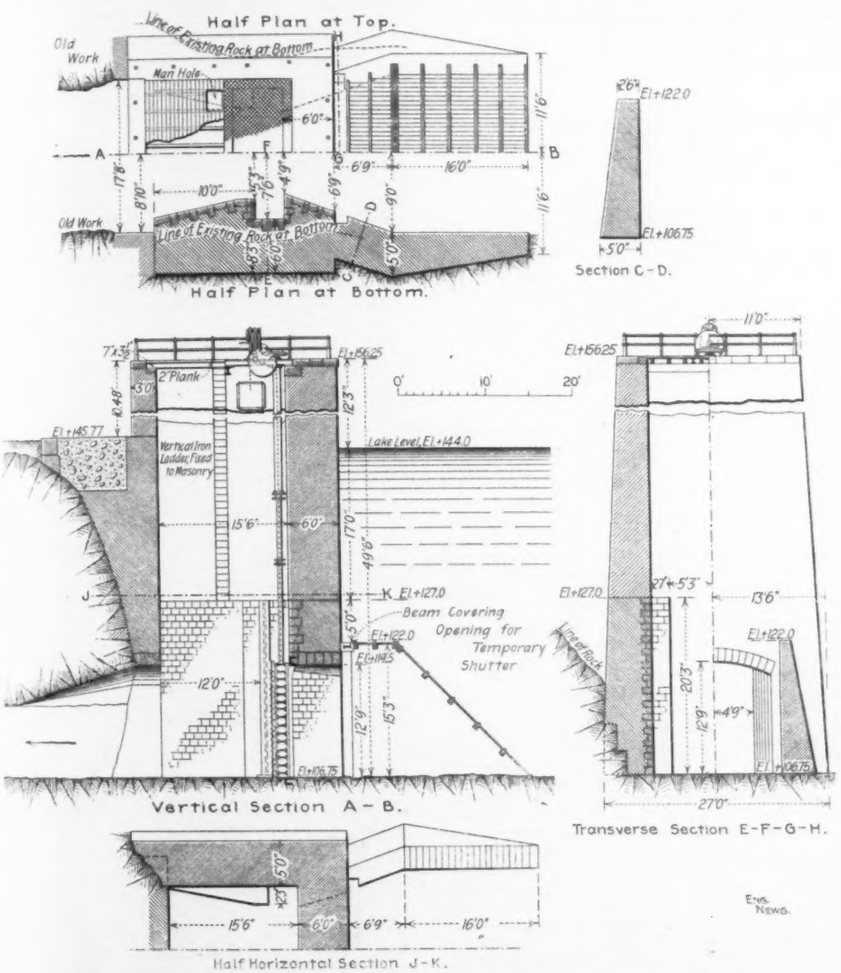

FIG. 11. DETAILS OF SLUICE GATE AT HEAD OF WATERSHED TUNNEL.

DISTRIBUTION SYSTEM.

The Periyar water after leaving the tunnel follows the channels of two natural waterways to Peranai, 86 miles, at which point the distributing canal system begins. At Peranai the principal structure of interest was the head sluice to the main canal. This consists of eight vents of 10-ft. span, with sluice gates 10¾ × 9 ft., worked by double screws. The area of the vents is 480 sq. ft., and they are designed to pass 2,016 cu. ft. of water per second with a velocity of 4.2 ft.

The main canal is 38 miles long, and from it diverge twelve branches. The depth of the main canal is 6 ft. throughout, and its capacity is 2,016 cu. ft. per second at the head, where the bottom width is 100 ft., and 288 cu. ft. per second at the foot, where the bottom width is 12 ft. The total fall is 71.19 ft., including four drops aggregating 19.25 ft. The side slopes are 1½ to 1 in earth and vertical in rock. There is a berm 10 ft. wide on each side flanked by a bank with side slopes of 2 to 1, a top width of 6 ft., and a height of 12 ft. above the bed. The branch canals were similar in construction to the main canal, but of course much smaller in dimensions.

The various collateral works—falls, culverts, sluices, etc., were so numerous that individual mention is impossible here. To give some notion of their number, however, it may be mentioned that on the 38 miles of the main canal there were 45 bridges, 12 surplus passages, three aqueducts, three regulators, four drops or falls, several sluices, 25 culverts and a number of smaller cross-drainage works. These works were all of masonry founded generally on bed rock, but occasionally on hard clay or kunkur. The spans were usually 24 ft. or 25 ft. to economize centerings, but in small or low arches earth centerings were often used. The arches were generally of concrete, but for spans of less than 7½ ft. slabstones were employed. The bricks in the neighborhood were bad, therefore the masonry throughout was of coursed rubble or burnt stone in mortar. The lime was burned from the kunkur found in the vicinity. The mortar was composed of 1 part lime, 1¼ parts sand and ¼ part surki by measurement, and the concrete of 2¼ parts stone to 1 part mortar in the arch work, and of 3 parts stone to 1 part mortar elsewhere. In arch work the concrete was laid circumferentially in 6-in. layers, and the top of each course was grouted. The centering was generally removed after a month but often much sooner. Nearly all the construction was piecework.

According to the latest estimates, the cost of the Periyar irrigation works is about as follows:

Head works	$2,009,600
Distribution system	771,000

The quantities and costs of the main dam works were about as follows:

3,330,571 cu. ft. of concrete		$442,275
2,406,183 " of rubble masonry		326,314
Total		$768,589

The area irrigated by the completed works will be about 100,000 acres.

THE NAVAL ESTIMATES for the year ending June 30, 1903, amount to $98,910,984; the appropriations for 1902 were $77,924,535. Among the more important items in the 1903 budget are the following: New York Navy Yard, $3,110,000; Norfolk yard, $1,208,500; naval station at San Juan, Porto Rico, $2,613,000, including $1,000,000 for a masonry dry-dock and $250,000 for dredging; for housing torpedo vessels at Pensacola, $650,000; dry-dock at Portsmouth, N. H., $500,000; Boston navy yard, $1,127,700; naval station at Tutuila, Samoa, $108,000; Cavite naval station, $381,000; complete naval station at Olongapo, Philippine Islands, $1,433,000; Boston naval magazine, $500,000; Portsmouth naval magazine, $400,000; naval magazine at Puget's Sound, $100,000; reserve guns for warships, $500,000; new batteries for the "Newark," "Albany" and "New Orleans," $375,000; for naval academy, $1,500,000.

THE EXPERIMENTAL CAR OF THE GERMAN ASSOCIATION FOR THE STUDY OF HIGH-SPEED ELECTRIC RAILWAYS.

The proposed plans for carrying out a series of experiments in high-speed electric traction on the military railway between Berlin and Zossen, Germany, have been briefly noted at various times in preceding issues of Engineering News. In a paper by A. Lasche, of Berlin, read before the International Engineering Congress at Glasgow, Scotland, the character of these experiments and the construction of the car with which they are to be conducted, are described at length. From the copious extracts from this paper, published in the London "Engineer" of Sept. 13 and 20, 1901, we have selected the following matter of most general interest:

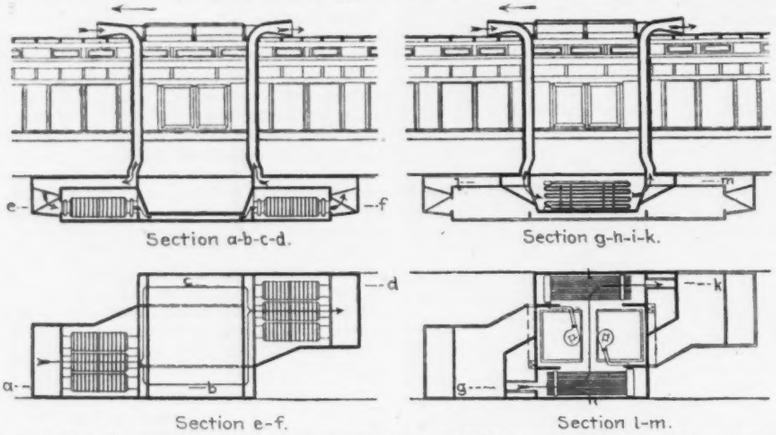

FIG. 1. DIAGRAM SECTIONS AND PLANS SHOWING METHOD OF COOLING TRANSFORMERS; HIGH-SPEED ELECTRIC CAR.

The German Association for the Study of Electrical High-Speed Railways has been formed, with the object of gaining experimental knowledge of the electrical working of long-distance railways, and as to the construction of the cars, the consumption of power, and the wear and tear of the permanent way, as well as of the limits within which railways can be run by electricity on a sound, technical and economical basis. The theoretical study of the question and the experiments resulting therefrom have up to the present time been of a general character only, and have had no reference to the planning of any special track. The first trials will be commenced shortly on the military railway from Berlin to Zossen, which the Imperial Military Railway Board of Administration has placed at the disposal of the association.

A speed of 200 kilometers—124 miles—per hour has been assumed as the maximum for the present construction of car, but this does not imply either, on the one hand, that the main object of the experimental line will be the attainment of this speed, or, on the other hand, that there may not be a possibility of running at still higher velocities. The trial has for its special object the establishment of a sound basis for the projection, construction and working of lines at the usual—or at higher—speeds. In certain technical journals and newspapers the attainment of a speed of 200 kilos. per hour has been ridiculed as being impossible, whilst in others it has been repeatedly asserted that this speed can be attained by steam locomotives. Indeed, the Americans claim to be able to travel at still higher velocities; and it is much to be desired that efforts should still be made in this direction with steam railways. In view of the present requirements of traffic, efforts must, of course, be made to travel more quickly, but special attention must be devoted to making traveling more convenient for the public; and electric traction is the best for this purpose. Naturally, the object of the present experiments and of those conducted during the next few years will be to compare the economy of the electrical systems with those in which steam driving is employed, and to ascertain the total cost of each system when running at different speeds, and especially at the higher speeds. It must be remembered that money was not treated as the main consideration when electric light and electric power were introduced. Indeed, even at the present day electric light is often much more expensive than gas light, and yet it is very extensively used. In the same way the electric working of railways is likely at first to be largely adopted in cases in which the higher cost—if, indeed, the cost should prove to be higher—may be disregarded on account of the greater convenience afforded by the system. In this way the introduction of electric long-distance traffic should be easily developed and universalized.

The ability to run separate motor cars in rapid succession is a great advantage in favor of electric driving, and such a service of motor cars has been proposed for use on suburban and long-distance lines. With this in view, the experimental cars of the association have been built in the form of passenger cars rather than as locomotives. This method of working with single cars, running without producing smoke and at short intervals, is already required by the public, and should therefore be remunerative. Another advantage attendant on electrical driving is that on lines on which the traffic is increasing the existing permanent way, bridges, etc., may be retained, because, in place of heavier locomotives and longer trains, light and separately running motor cars will be used.

The permanent way and its maintenance are, of course, very important considerations in connection with the electric system, and further considerable improvements are necessary, but the trials about to be made by the association should show to what extent the wear produced by electric locomotives is less than that caused by steam locomotives.

The experiments will, it is hoped, establish a basis for the calculation of the working expenses of electric main lines, and also of the outputs of motors for the various speeds and the increasing influence of air resistance, as well as for the determination of the size of power stations necessary. The lower limit of speed at which electrical may be more economical than steam traction is about as little known as is the higher limit. All that is known is that with steam locomotives the consumption both of steam, and more especially of coal, is very greatly increased with increasing speed. But by centralizing the generation of power the circumstance will, of course, be entirely different. Large steam engines of the best construction may then be used with boilers provided with superheating and feed-water heating apparatus. This centralization—and consequently the attainment of a practically uniform load—is now possible for very long distances. Three-phase alternating current can be generated at a pressure of 40,000 or 50,000 volts, so that electrical energy can now be transmitted for very great distances without serious loss, and all the railway lines over a large area can be supplied with current from a central station placed in a favorable situation.

NATURE OF CURRENT USED.—As the problem to be solved is that of long-distance transmission, the current to be adopted should be three-phase alternating current of high voltage. For the experiments to be described a current of only 10,000 to 12,000 volts was necessary; it was supplied by the Oberspree central station of the Berliner Elektricitäts-Werke, the distance from the central station to the nearest point on the trolley wire being about 15 kilos. (9.3 miles). At present the current supplied to this wire is at a pressure of 10,000 to 12,000 volts, and the transformers are mounted in the car itself, a low voltage—435—being used for the motors. With regard to future developments, it is still an open question whether it will be advisable to keep the heavy weight of the transformers within the car or whether it may not be preferable to reduce the high pressure—about 50,000 volts—by transformers alongside the track to a medium pressure of about 3,000 volts, and to wind the motors for this latter voltage.

The conversion of three-phase into continuous current is not practicable for the service of long-distance railways, because it requires the use of rotating machinery and consequently necessitates attendance, whilst transformers for varying the potential of three-phase current have no moving parts. Moreover, continuous current demands the employment of a very low voltage, and therefore of short distances between the transforming stations. It might, however, be necessary to use continuous current for long-distance cars while passing through a large town, the three overhead wires of the three-phase system being inconvenient for points and crossings; a slow-speed locomotive could then be coupled temporarily in front of the car.

INVESTIGATIONS.—The problem set to the Allgemeine Elektricitäts-Gesellschaft was as follows: To construct a motor car to run at a speed of 200 kilos. per hour and to accommodate 50 persons, the car to have two trucks with three axles each and the motors to be designed for a total output 1,100 HP. normal and 3,000 HP. maximum, the electric current provided to be three-phase at 12,000 volts and at a frequency of 50 complete periods, the weight of the cars to be as small as possible, but on no account to exceed eight tons per wheel, and the shape to be such that the car is within the standard structure gage necessary to allow it to pass over the lines of the State Ry.

The second part of the present paper contains the description of the car and its electrical arrangements. In the first part some of the preliminary experiments and investigations are described, as they are of special interest in view of the novelty of the whole system. The description of these investigations shows in the clearest possible way the results which it was sought to attain.

Although primarily experimental, the car has been constructed to run permanently at any speed decided upon after the trials have been completed. It must not, of course, be compared with the ordinary tramcar or with the low-speed locomotives, for the motors, the transformers and the starting and regulating apparatus are of an entirely new type. In this paper an account is given of the attempts made to attain the lightest possible weight both for the car and for the electrical equipments i. e., transformers, motors and apparatus. In view of the high speed desired, the company thought it necessary to find means to relieve the axles from the heavy weight of the motors, or at least to prevent the axle from being directly burdened thereby. The starting and regulating apparatus for a 3,000-HP. car could not be constructed of the same type as that used for the ordinary controllers for cars taking hardly 100 HP. Experiments on a very large scale were therefore necessary in order to test the novel arrangements. Braking at a speed of 200 kilos. per hour by means of friction brakes—that is, at a peripheral speed of 184 ft. per second—was found to be unsatisfactory, and it was therefore necessary to provide means for braking electrically. A large number of other new details had also to be designed. The motor bearings have to work at a surface speed of about 46 ft. per second, the collecting rings of the armatures at a speed of about 131 ft. The trolleys required special consideration and presented one of the most difficult of the problems to be solved.

PRELIMINARY EXPERIMENTS AND INVESTIGATIONS.

(1) WEIGHT OF THE ELECTRICAL EQUIPMENT.—The three main conditions—the stationing of the driver at the front of the car, the placing of the apparatus at the place which calls for the shortest cable connections, and the devotion of every consideration to the comfort and safety of the passengers—led to the development of the following design: The whole of the apparatus, cable and

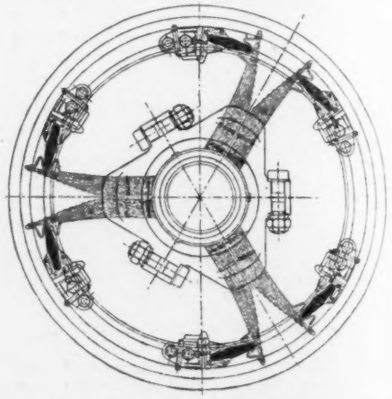

Fig. 2. Spring-Coupled Driving Wheels; High-Speed Electric Car.

safety devices are arranged in the middle compartment, which, with the transformers below it, is separated from the passenger compartments by air shafts with double iron walls. The driver always stands at the front of the car, separated from the passengers, in a compartment in which there are no connections at high electrical pressure. The control is effected from the driver's platform by mechanical transmission.

It has already been stated that the transformers had to be mounted in the car itself, although they add much to the total weight of the car. In making the calculations for the transformers and determining the cross sections necessary for the iron, the question of the heating and cooling of the iron and of the upper coils is of the greatest importance. The cooling of the transformers by air taken from below the car is impossible, on account of the large amount of dust produced when traveling at a high

speed. On the other hand, the designs showed that a great gain in weight is possible if air is passed through the cores of the transformers and the insignificant amount of cooling possible from the surface of the casing is not alone depended upon. Two air shafts led from the roof (Fig. 1) to the transformers in such a manner that the front shaft was used for the admission of fresh air, and that in the rear for its emission after it had become heated. Special care was taken to withdraw the moisture from the air in rainy weather and to ensure that it is dried and filtered before it enters the channels of the transformers, although the actual contact of the cooling air with live conductors is avoided. Further economy resulted from the use of a liquid starting device of an entirely new construction, instead of the metal starting

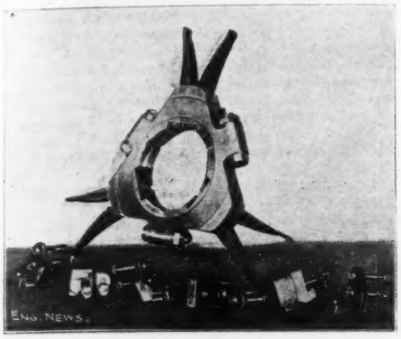

Fig. 3. View of Spring Coupling Dissembled; High-Speed Electric Car.

device with coils or plates of resistance material at first provided.

The following summarized statement shows how the weights varied in the different investigations:

Weights.	I. Kilos.	II. Kilos.	III. Kilos.
Four motors	16,000	16,000	12,800
(a) Two transformers	13,000	13,000	6,500
(b) Starting resistance with casing (c) Controller with driving mechanism	9,000	9,000	4,750
(d) Braking and lighting batteries	2,600	2,600	2,600
(e) Motor with compressor	800	800	800
(f) Oil pump	200	200	..
(g) Oil tank	600	600	..
Total weight of cable	4,000	1,000	1,000
Trolley poles	1,400	1,400	1,400
Total	47,600	44,600	29,850

The final weight for the transformers was 14.3 lbs. per K-W., and for the motors 28.7 lbs. per HP. for the normal output and 9.5 lbs. per HP. of the maximum output, a saving which resulted from the construction of the unenclosed motors. Like the new alternating-current dynamos and the stationary motors, the laminated iron magnets are not encased, but are directly exposed to the cooling influence of the air, the external surfaces of the motors being increased in area by the ribbed design adopted. Surface cooling was thus ensured in a convenient way; it was found to be fully sufficient even when the motors were running continuously. No provision was made for the admission of air into the motor, as, on account of the dust below the car, it was not possible to take the air from below, and there was no convenient way of supplying it from above.

(2) THE MOTORS SPRING-MOUNTED AGAINST THE AXLE OR RIGIDLY SECURED TO THE AXLE.—Between the two extremes—(a) the body of the car mounted without springs directly on the axles, and (b) every part being practically mounted on springs, as in an automobile with pneumatic tires—a large number of different combinations is possible. Electric locomotives of very small dimensions have been constructed with the upper part in rigid—not spring-mounted—connection with the sets of wheels. On the Central London Underground Ry., notwithstanding that a speed of 30 kilos. per hour is attained, the trucks of the locomotives are not mounted on springs; hence the severe vibration which has caused so many complaints. Others have adopted different constructions. Some have placed the motors directly on the axles, whilst others have fixed them to the spring-mounted body of the car, or to the truck. The motors carried by the truck have the same range of movement—due to the deflection of the spring—relatively to the wheel axles as the frame itself has; i. e., up to a maximum of 2.3 ins. in one direction.

The simplest construction is, of course, the rigid mounting of the axle on the truck. In this case the axle and the motor have no motion relatively to the other parts of the construction, but unfortunately the axle boxes have here to ensure the central position of the revolving armature within the fixed stator.

In another construction the stator is kept concentric with the rotor by being mounted on the same axle, which thus carries the weight of both, and the power is transmitted from the axle to the wheels. The stator must be so connected to the frame that it is prevented from rotating.

In another arrangement the motor is rigidly connected to the truck, which is spring-mounted on the axle. The indirect use of springs in supporting the motor—by attaching the stator to the frame of the truck—necessitates the use of a hollow shaft surrounding the axle at a suitable distance. This construction may be possible when the springs between the frame and the axles are not subject to such deflection as they are liable to in the high-speed car, where the play may amount to 60 mm. or more. In this car there is a peripheral speed in the bearings of not less than 18 m. per second (3,540 ft. per minute). As no previous records were known of the use of white-metal bearings at these extraordinary high speeds, a series of experiments was undertaken in this connection, quite independently of the other investigations. The material at first used for the hollow shaft was cast-steel, due regard being paid to cooling; but this was subsequently abandoned and wrought nickel-steel was substituted, because its surface is capable of taking a very high polish.

One of the chief difficulties in designing the coupling and bearings was the considerable deflection of the springs when the motor was attached to the car or truck; it has been stated also that arrangements for supporting the motor by a number of small springs did not appear to afford sufficient security, although the motion of a few millimeters should be sufficient. The motor was no longer connected with the frame of the truck, but it was supported by strong springs bearing against the axle-box. These springs had to deflect but a few millimeters. By means of an adjustable curved block for the first one or two millimeters this spring bends very readily, then the spring grows stiffer up to a maximum of 8-10 mm. The engravings show the construction of this arrangement. The motor is firmly screwed to a frame of sheet iron with channel iron bars. This frame is supported on both sides of the car on plate springs, resembling the usual car springs, the buckle being mounted by means of the buckle of the axle spring at the axle-box. The motor is prevented from moving laterally by suitable abutments, which bear against the slides. Means were also provided to prevent rotation of the stator in either direction. Alterations which were made during the manufacture will be referred to later. With this simplified construction it was possible to make the coupling shown. In the form shown in Figs. 2 and 3 this frictional resistance is diminished to less than 1%, or, in other words, it is practically obviated. The reduction in the deflection of the spring allows the diameter of the hollow shaft to be diminished, and so the construction of the bearings is simplified and their lubrication is facilitated.

(3) STARTING DEVICES.—In the investigations relating to the main division of the car and to the arrangement of the electrical parts to ensure the attainment of the minimum weight, it was mentioned that the starting apparatus was mounted in the middle of the car so as to allow of the cables being as short as possible. It was at first intended that liquid starting devices should be used in starting and regulating the current, the construction ordinarily used for starting either small or large motors being employed. Thus, wrought-iron sheets were to be inserted in the armature circuit of the motors in such a manner that connection would be established by the liquid and the armature circuit would thus be closed; it would then be opened by withdrawing the sheets from the liquid. For constructive reasons the electrodes cannot be placed sufficiently close together to produce a short circuit even when totally submerged, and it is therefore necessary to use a metallic short-circuiting device. Further difficulty in the case of large motors is that involved in the movement of heavy electrodes. The problem was finally solved by a liquid starting device on an entirely new principle. A three-phase current motor of 200-400 HP. is coupled direct to a very heavy fly-wheel. In order to bring this up to full speed in 15 secs., a torque corresponding to an output of 400 HP. must be attained. A small centrifugal pump driven by an electro-motor raises the liquid from a reservoir in the basement, and continually delivers it into the tank in which the electrodes—i. e., the terminal or end plates of the opened armature circuits—are located. The pump operates continuously; hence a constant renewal and mixing of the liquid takes place, and the electrodes are thus suspended, not in stationary, but in moving water.

The essential difference between the new starting device and those previously used consists in the maintenance of the liquid in constant motion—a fact which alone suffices to ensure its use. The heated liquid does not remain at the point where heat is being generated, but is constantly circulated and mixed afresh. It is easy to calculate what amount of heat is communicated to the liquid by the resistance at any given load, or for a given decrease in the normal speed; and the use of water in motion renders it easy to conduct away this heat. The cooling surface necessary to effect this may be readily calculated; and in the present construction of the high-speed car systems of serpentine copper tubes of small diameter are provided, through which the heated water has to pass after leaving the electrode vessel and before it is used afresh. Consequently the new liquid starting device enables any suitable large resistance to be brought permanently into the circuit, and the motor can be run continuously at any slow speed that may be required.

Owing to the great simplicity of the apparatus, it can be readily operated from a distance, as the power required is excessively small. Consequently the provision of compressed air or electricity in the car as a means of operating the reversing mechanism is rendered unnecessary; all that has to be done is to provide a connecting shaft operated by a hand wheel from each driver's platform. When using the new system of liquid starting device the metallic arrangement is no longer needed, and the several hundred contacts and cables are dispensed with. In regard to maintenance no fear need be entertained, since, of course, the maintenance of plates not liable to become rusty, immersed in a soda solution, cannot be compared with that of many and large controller cylinders, contacts, contact brushes, cable connections and pieces of resistance material.

(4) BRAKES.—The system of electrical braking with the aid of the motors was also tested by means of the same experimental arrangement that had been constructed for testing the starting apparatus. The car is equipped with a Westinghouse compressed air brake, divided into two parts for each of the two trucks. The compressed air cylinders are operated from the front driver's platform. The brake pressure is assumed to be very high—170%—because the coefficient of friction between the brake block and wheel at the high speed employed—above 50 m. per second—is materially different to that at the usual lower speeds. In consequence of investigations that have been made, an appliance has now been devised for decreasing the brake pressure at a gradual slow speed. Notwithstanding the fact that to a certain extent the brake arrangement of the one forms the reverse for the other truck, it was not considered admissible to dispense with a second brake. This additional braking action was imparted by the motors themselves, and not by special rail brakes or similar less approved apparatus.

The braking or retarding action can be effected by means of an electro-motor in one of two ways—either by eddy currents, namely, by energizing the field of the motor with continuous current and short-circuiting the armature, or by reversing the direction of the rotation field. Both kinds of brakes are used in the high-speed car. After the armature circuit is opened by opening the outlet valve of the liquid starting device, the field is cut out and switched on to a storage battery placed within the car, or reversed to opposed current, with two of the three phases reversed, the series arrangement of the phases being changed from 1, 2, 3 to 1, 3, 2 and 3, 2, 1, respectively. After the switching has been effected in either way, the armature circuit is gradually closed again, i. e., the inflowing liquid makes contact under very great resistance,

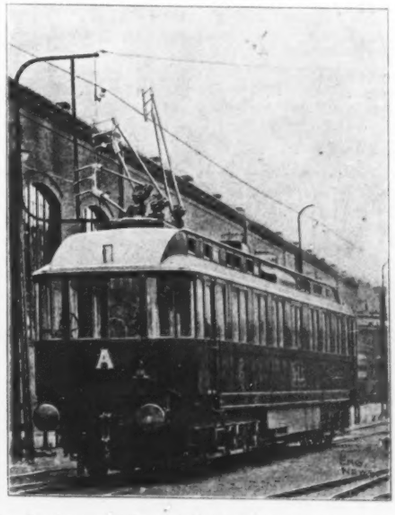

Fig. 4. General View of High-Speed Electric Car of the German Association for the Study of High-Speed Electric Railways.

and the level of the liquid is then raised or lowered, according to the amount of braking action that may be desired.

Braking by means of counter current alone did not appear to be sufficient, because the current was apt to fail for some reason or other, as, for instance, by the melting of a safety fuse at the very moment when the brake was applied. The use of a counter current has a further disadvantage. In consequence of the electrical construction of the motor and the potential of about 430 volts selected for the field, the armature has an electric pressure of about 325 volts on open circuit. After the reversal of the field the tension in the armature increases at full speed to almost double this amount, viz.: to about

650 volts. Although the liquid starting device is intended for this voltage and the motor armature is also fully capable of sustaining it—it was tested at 4,000 volts—yet it appeared unwise to allow the safety of the braking action to be dependent on an unusually high voltage just at the time when the brake is brought into action, and when there is a possibility of danger. These were the reasons which led to the provision of an eddy current braking system, and for this purpose there were two entirely separate storage batteries, corresponding to the two separate air receptacles for the Westinghouse brake. It is here assumed that motor braking must be made use of at high speeds, and that the air brake is only applied at the end of the run. For shunting service, a hand brake is provided to act on the front truck.

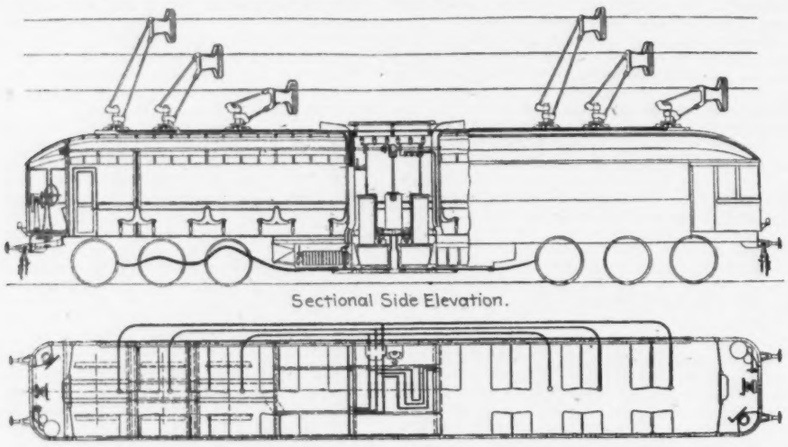

FIG. 5. LONGITUDINAL SECTION AND PLAN OF HIGH-SPEED ELECTRIC CAR, SHOWING ARRANGEMENT OF MACHINERY.

(5) TROLLEY-BOWS.—The current is led to the three vertically superposed wires, from which it is taken into the car through bow-shaped collectors. By this system of taking the current, in which a deflection of the trolley wire between the connecting points does not affect the bow, the jumping of the latter is more readily avoided than if it made contact from below. Notwithstanding this fact, the question of the trolley-bows had to be very carefully studied, and although the requirements for a speed of 50-60 m. per second could only be very incompletely complied with, an experimental arrangement was nevertheless made. Three arms are arranged on the roof at each end of the car, one for each of the three phases. The distance between the arms is determined by the space required by the bows when being turned around their vertical axis. These distances are, however, made as small as possible, and the arms are located close to the pivots of the trucks, so that there may be no material change of the distance to the wires in passing round curves. Two systems of bows were considered necessary, so that, in the event of one bow failing to act, the current would be taken from the other and no sparking would occur. Further steps were then taken in the direction of increasing the number of contact surfaces and of reducing as far as possible the mass of the metal which has to slide along the wires. A number of aluminum bows were connected to the trolley pole by plate springs of different lengths. The object of this elastic arrangement was to ensure a good permanent bearing on the wire, but in the event of one bow failing to make contact the others must be sufficient to carry the current. In the event of greater deviations of the conducting wire taking place, the main spring arrangement of the whole arm will begin to act. Further particulars are contained in that part of the description which treats of the manner of taking and supplying the current.

DESCRIPTION OF THE CAR AND ITS ELECTRICAL EQUIPMENT.

THE BODY OF THE CAR.—The car, Figs. 4 and 5, specially constructed to suit the electrical equipment was built by the firm van der Zypen & Charlier, of Cologne-Deutz, to accommodate 50 passengers. The overall dimensions of the body of the car, including the apparatus compartment and driver's cabs, are 21 m. (69 ft.) and the distance between the buffer plates 23.10 m. (72½ ft.). The full width of the car is 2,600 mm. (8 ft. 6 ins.). The body of the car is within the standard profile throughout its length, but—especially in the middle part, with its wide air ports—there is not much margin to spare in this respect. The windows of the car are closed, ventilation taking place through the side window of the lofty skylight. On either side, at each end of the car, doors are provided to allow of the entrance and exit of the passengers. The driving platform is separated from the passengers' compartment by a wide partition extending from the bottom to the top of the car and serving as a back support for the driver. At the sides of this partition are grated doors which, during stoppages at stations, are arranged in such a manner that the compartment remains shut off from the passengers, without interfering with the free access of the latter to the interior of the car. During the run these doors are so adjusted that they prevent the passengers both from reaching the exit and from disturbing the driver. The car is divided into two compartments by that containing the apparatus. The passengers can, however, freely pass from one compartment to the other, even when the car is in motion, as the apparatus compartment is protected in the same way as the driver's platform. Any portion that is liable to be touched from the gangway either does not carry current or is suitably insulated.

As will be seen in the section devoted to the arrangement of the cables, neither the passenger compartments nor the driver's platforms are under current. The trolley-bows on the roof of the car are fitted with two insulators connected in series, each of which is tested for a potential of 20,000 volts. The high-tension current passes from the bows to the transformers through high voltage cables which, in spite of their having been tested for 20,000 volts, are laid in high-tension insulators. Between the so-called apparatus compartment and the passenger compartments, and also between the latter and the transformers which are suspended below them, there are air shafts which form a double-walled enclosure. The storage batteries alongside the transformers are likewise separated off by double sheet metal walls.

THE RUNNING GEAR.—The two trucks which carry the body of the car are 13.3 m. (43 ft. 7 ins.) apart. The diameters of the wheels were assumed to be 1,250 mm. (49.2 ins.), which allowed for a sufficient turning movement of the trucks below the car without necessitating any alteration in the floor level at any part of the car. Each of the trucks has three axles, the two outer axles carrying the motors, while the middle axle allows the necessary space for the pivot and for the air cylinders of the Westinghouse brake. The distance between the wheels measures 2 × 1,900 mm. (12 ft. 6 ins.). Fig. 6 shows one of the trucks and the arrangements of the motors within it. The load for each axle is less than the maximum allowable, and amounted to a little over 14 tons. No springs bearing against the body of the car are provided. The trucks themselves are supported on the axles by two sets or springs; and each axle-box carries a strong plate spring, to the heads of which are attached supporting springs carrying the frame.

On these axle-boxes rests the shoe of the axle spring; plate springs are provided to carry the motor. The connection between this spring and the motor frame is established by a curved block, against which the spring bears. By means of these shoes the spring action or its degree of elasticity can be varied. For the first few millimeters it acts as a very mild spring, then it gradually becomes more rigid and at a deflection of 8 to 10 mm. is quite stiff. In the almost impossible event of these outer springs breaking, the motor would be supported by the wheel axle with the interposition of a suitable metal packing, placed close to the side of the wheel hub. The conditions to be observed in the selection of material for this packing were that the material should be sufficiently soft to protect the axle and hollow shaft, yet of sufficient resistance to bring the car to a standstill before serious damage could be done. The motors are firmly screwed to a frame formed of rolled plates riveted together, and are protected against lateral movement by guide blocks, which bear against a corresponding guide on the frame of the truck. The stator is prevented from turning round by bars which only allow of a vertical movement of the motor (Fig. 6). The transmission of the power from the motor to the wheels is effected, as already indicated, by an elastic coupling, which is entirely independent of the bearing.

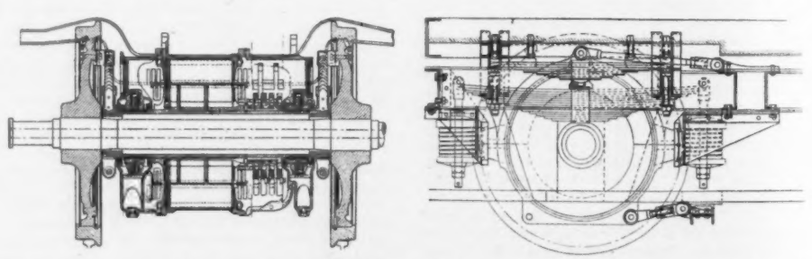

FIG. 6. ELEVATION AND SECTION SHOWING METHOD OF MOUNTING THE MOTORS; HIGH-SPEED ELECTRIC CAR.

THE MOTORS.—Each of the eight motors is adapted for a normal output of 250 HP. and for a maximum output of 750 HP. The speed of the motor is about 900 revolutions per minute, which corresponds to a car speed of 225 kilos. (140 miles) per hour. The tension of 12,000 volts, at which the current is supplied from the overhead wire, is reduced in the transformers to 435 volts. This voltage was adopted so as to permit of the motors being constructed with bifurcated winding. Although the motor, as above stated, is not subjected to severe mechanical shocks, it was nevertheless deemed advisable, to ensure permanent safety in working, to have only one single bar in the separate grooves instead of a number of wires insulated from each other by cotton covering. The insulation of the bars from the iron is effected by closed micanite tubing. The armature winding—at the tension of the regulating apparatus—like the field winding—transformer low tension—is also bifurcated. For sake of convenience in the starting apparatus and the arrangements of the cable, the armature was wound for only two phases, and not, as is usual, for three phases. The stator, by means of two bearings, carries the hollow shaft on which the rotor is built up. One of these bearings carries on its upper half the brush gear for making contact with the slip rings, and the connections for the cables of the armature circuit which lead to the regulating apparatus. The cables of the casing circuit are passed through the other bearing. The bottom halves of the bearings can be easily removed to allow of the removal of the brasses and to give free access to the brush gear.

The spring couplings are fixed to the hollow shaft at both ends. The object of this coupling was to transmit the power developed by the motor—750 HP. maximum at 900 revolutions—from the hollow shaft to the wheels, thereby allowing the wheels a displacement of 10 mm. relatively to the coupling arms. Hence the arms had to be elastic, and, moreover, the head must be able to slide against the guides mounted on the wheel. The construction of the whole required a division of the coupling into three parts, corresponding to the three double arms that were adopted. The springs are secured in the annular pieces by wedges in such a manner that the tension of the wedges is further increased by the centrifugal force applied. Furthermore, the plates are extended laterally within the hub, and are thus prevented from flying out. The hub portions are of forged steel, of ample cross-section. The power is transmitted by means of keys from the hollow shaft to the three-part hub of the coupling.

TRANSFORMERS.—The three cores of the transformers are arranged side by side in accordance with the patents of the A. E. G. (Fig. 7.) The axles of the cores run longitudinally in the car. The current transformation being from 12,000 volts to 435 volts, a massive copper spiral is used for the low-voltage winding, and the outer, or high-voltage, winding is separated from it by a micanite cylinder. A strong current of air passes through a longitudinal channel provided in each of the iron cores, and also through the space between the square cores and the round inner coil. As already mentioned, the air for this purpose is received through large air holes in the roof, and is delivered through air ducts to the transformers. A protecting angle iron is provided on the roof for the removal of rain water, and before the air enters the shaft and the channels it passes several times through wire netting with wide meshes; the air is then conducted

over the transformer and filtered again before entering the cores. In spite of these precautions, the air is only brought in direct contact with the interior of the cores of the transformer and not with the parts carrying current. The cores are supported in the middle of their length to obviate any deformation due to the vibrations of the car. The transformer is suspended to the body of the car by draw-bolts, so that the lateral sheets are only used for lining purposes and are not called upon to carry any load. A further addition of springs connecting to the body of the car did not appear to be necessary, because the present arrangement is similar to that adopted for the International sleeping cars, and should suffice to ensure a long life for the insulating materials.

CABLES.—The current is taken from each of the three feeding wires by two trolley bows in parallel, Fig. 5. The upper part of each of these arms carries a number of aluminum rods attached by means of narrow plate springs. The masses of the individual rods must be sufficiently small to ensure that they bear constantly against the wire. The head of the arm carrying the bow is pressed out of aluminum sheet, and is connected to the vertical base by rods, the base being mounted on ball bearings in the socket on the car. The bow is pressed against the wire by springs, the tension of which is regulated by means of cams. The current is carried by insulated leads from the head of the bracket to the foot of the arms that take the current, and is thence transmitted to the cables affixed to the roof of the car. The making or breaking of contact between the bows and the wires is effected from the interior of the car, so that the bows can be made dead before any person mounts to the roof. All high-tension conductors must have been subjected to an insulation test of 20,000 volts; but, notwithstanding this, they are placed on high-tension insulators, and are thus treated as if they were bare wires.

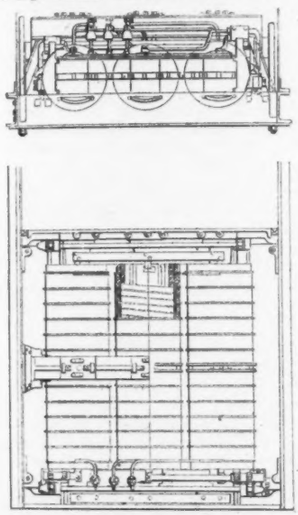

Fig. 7. Elevation and Plan of Transformers; High-Speed Electric Car.

Safety fuses are fixed close to the single bow; these operate as soon as contact is made from any cause between any phase and the earthed car, and the car is thus freed from current by the melting of the fuse. The wires of both collector systems lead from the safety fuses to the high-tension cut-out. This cut-out is not requisite for controlling purposes, and serves merely to cut out the tension at the end of the run. The switch may be operated from the apparatus compartment, or from either of the driver's platforms, so that it serves also as a safety switch in the event of the proper switch failing to act as the result of an accident. The two branches of the current pass separately from this main switch to the transformers of the truck. Each of these circuits and transformers is protected by fuses. The low-tension conductors lead from the transformers through a switching device to the motors. On account of the play to be allowed between the truck and the car, in regard to both the lateral oscillation when running round curves and the vertical deflection due to the action of the springs, the cables had to be suspended from flexible supports; this was effected by hanging them from a strong girth or belt. The cables leading from the motors back to the starting device are secured in a similar way.

The switch above referred to effects the admission of the current to the motor casings from the transformers, and it also allows of the adjustment for either direction of the driving or the delivery of counter current. Again, the storage battery is connected from this point to the stator circuit of the motors when braking the car as an automobile, i. e., when braking independently of the overhead wire.

DRIVING THE CAR.—The car driver has only to operate one single hand wheel in order to carry out all the manipulations. By means of an indicator he can at any time ascertain the position of the apparatus, and by an ampère-meter he ascertains the load on the motors; another apparatus continually indicates the speed of the car. By the hand wheel the driver operates a shaft extending through the entire length of the car. The switch is operated from this shaft by means of a pair of bevel wheels and cam wheels. The movement of this cam gearing to the extent of one tooth effects the switching of the controlling cylinder to forward current, reverse current or braking action. On the left of the driver is the handle for the operation of the compressed air brake and on his right there is another, a hand wheel, for the hand brake to be used in shunting. It is proposed to employ a number of different kinds of measuring apparatus on the trial trips, especially with the object of indicating the acceleration of the speed, of measuring the air resistance met with in head and cross winds and of measuring and registering the consumption of current.

A PROPOSED WATER POWER ELECTRIC TRANSMISSION PLANT FOR ST. PETERSBURG, RUSSIA.

We have received from a Russian engineer, M. Dobrotvorsky, of 3 Malaia Masterskaia, St. Petersburg, an account of a project for the development of extensive water powers near St. Petersburg with electrical transmission to that city. As the power available is very large, and the population to be supplied numbers nearly 1,500,000, the enterprise, if carried out, will rank as one of the greatest electrical undertakings of the times.

The scheme comprises the necessary hydraulic works on three large rivers, three turbine generating stations of 28,000 to 38,000 HP. each, high voltage transmission lines to St. Petersburg (respective distances of 68 to 106 miles), transformer and distributing stations in the city and at required points along the line, a complete distribution system in the city, with navigation improvements on the rivers referred to, etc.

The location of St. Petersburg is peculiarly favorable for such power development. Lake Saima to the north, Lake Peipus to the southwest and Lake Ilmen to the south, each with a drainage area of about 30,000 sq. miles, flow to sea level through short, steep outlets, the rivers Vuoksa, Narova and Volkhov, which, at distances of from 70 to 100 miles from the city, present almost ideal opportunities for water power development.

At the rapids of the Volkhov, 68 miles from the city, the scheme calls for a stone dam just below the rapids giving a fall of 38 ft. and rendering 38,000 HP. available. The utilization will be effected by 18 turbines (of 2,080 HP. each) driving 54 dynamos of 500 K-W. capacity; the energy will be conveyed to the city over two lines of copper, each of six conductors of 0.15 sq. in. cross-section, giving a total of 0.90 sq. in. of line section. The dam is to be of special design, with movable top section, to facilitate free passage of floodwaters and ice, while locks in connection will provide safe navigation, which is at present uncertain and dangerous. The free communication by water with Lakes Ladoga and Onega, penetrating the rich mineral fields of Olonetz, is expected to attract numerous large industries to the site. It is proposed, further, to install electric traction in the Ladoga canals, near which the transmission lines will pass.

The River Narova breaks into a series of rapids and a short fall near the town of Narva, situated 85 miles from St. Petersburg on the Gulf of Finland and on the line of the Baltic railways. The works for the utilization of the water power here are in general similar to those at Volkhov. The existence of several factories at the fall makes it possible to utilize only 34½ ft. head instead of the full 38 ft., and cuts down the available power from 50,000 to 28,000 HP. The transmission line will consist of two lines of four copper conductors of 0.18 sq. in. cross-section each, a total of 0.72 sq. in. line section. The water and rail facilities promise an extensive industrial settlement at Narva, and considerable development of the provinces around the head of Lake Peipus.

On the Vuoksa the rapids and water fall of Imatra occur at a distance of 106 miles from St. Petersburg. Due to the height of fall, the hydraulic works will differ from the other two. It is proposed to construct a canal to divert about one-fourth of the water now flowing over the falls, returning it to the lower reach in an artificial cascade and rendering 38,000 HP. available. The generator plant will be closely similar to that of the Volkhov; the transmission line, however, the longest of the three, will consist of two lines of six conductors of 0.21 sq. in. cross-section each, giving 1.26 sq. in. total line section.

The distribution system within the city is to consist of eight circuits, aggregating 112 miles of mains. It is considered possible that some of the existing mains may be incorporated in the system. The consumption to be expected shortly after completion and its distribution are estimated as follows:

300,000 incandescent lamps	16,800 K-W
4,000 arc lamps	3,200 K-W
Tramways	3,600 K-W
General power purposes	25,000 K-W
Total	48,600 K-W

The city is to be supplied free of charge with electricity for street lighting and all other municipal purposes, and it is calculated that rates for private use can be made less than one-half the existing rates.

The system as outlined will supply a total of 66,000 HP. delivered at the transformers, giving an average of 4,700 HP. per sq. mile in the city. The three separate sources of power are planned for interconnection so as to render impossible the entire failure of electrical supply. The complete scheme includes provision for future extension, for utilization of part of the profits for construction of works for impounding of water in the head lakes so as to increase the available dry weather flow, etc.

The cost of the enterprise is estimated at about $14,000,000, the operating and general expenses at $2,750,000. A company has already been chartered by the government to construct the necessary works.

At present St. Petersburg is supplied with electric light from ten central stations, and there are besides some 250 isolated plants. The combined capacity of all these private and public plants is estimated at 51,000 HP., and the total number of lamps supplied is estimated at 450,000 incandescent and 3,500 arcs. With the long winter evenings, due to its far northern location, the demand for light is a large and steady one. The supply of current for the electric railway system shortly to be established will also absorb a large amount of power.

While the distance of transmission is considerable, the fact that steam power is now developed with imported English coal makes the proposition to develop water power and transmit it electrically to the city a very attractive one.

MR. NIKOLA TESLA'S TRANS-ATLANTIC WIRELESS telegraph station, at Wardenclyffe, L. I., has materialized up to the present in the shape of one building about 100 ft. square, which is intended later to serve as a power house for the remainder of the plant. Boilers and an engine generating 250 HP. are now being installed. The land holdings of Mr. Tesla at Wardenclyffe are quite extensive, amounting to about 600 acres. Mr. Tesla claims to have perfected a method of communicating without wires at all distances, his system permitting any number of transmissions operating simultaneously with absolute privacy for each.

AN ARTILLERY SCHOOL OF MINES is recommended in the report of Gen. John. R. Brooke, Commanding Department of the East. He points out that in case of an invasion skilled officers and men should be on hand to execute, in less than one week from the declaration of war, the approved project for the planting of mines in all the harbors. To operate these mines in the United States and its distant possessions would require about 70 officers and 2,700 trained men, with an addition of 5,000 laborers and boatmen at the time of planting. All officers employed in this service should be experts in electricity; while the examination of officers transferred from the other branches of the army to the artillery does not include even an elementary knowledge of electricity. As civilians cannot be held to service or punished for malfeasance, Gen. Brooke says that some scheme should be devised for operating all defences under a military organization. There is a school for electrician sergeants now at Fortress Monroe, and this school should be attached to the one proposed. At present all mining material is generally cared for by civilians paid by the Engineer Department; it is recommended that electrician sergeants be put in charge of this material, one to each harbor equipped with mines.

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CHARLES WHITING BAKER, SECRETARY AND MANAGING EDITOR.
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ADVERTISING RATES: 20 cents a line. "Want" and "For Sale" notices, special rates, see page XXIV-XXIX. New copy for standing advertisements should be received one week in advance of publication; new advertisements, Monday morning. The pages containing "Want," "For Sale" and "Proposal" advertisements are held open until Wednesday noon.

Fresh instances of the unsatisfactory management of garbage disposal by municipal authorities in this country are continually occurring. The city of St. Louis has repeated the blunder which New York made a few months ago, and delayed advertising for bids for the disposal of its garbage until the existing contract had nearly expired. The result was that only a single bid was received. That bid was from the present contractor, and the price named was (at least on its face) almost exactly double that paid under the old contract. Months ago an effort was made at St. Louis to have bids for garbage disposal called for at once, so that some competition for the work could be secured; but although the present contract expires on Nov. 17, it was not until late in September that bids for a new contract were invited. Even then bidders were limited to the Merz system of reduction, which system has been in use for ten years past by the St. Louis Sanitary Co. The old contract was for ten years, at a rate of $1.80 per ton up to 100 tons of garbage a day, or $65,700 per year, since all over the amount stated has been treated without charge.

The new contract, just awarded to the St. Louis Sanitary Co., is for three years, at a monthly rate equivalent to $130,000 a year. It appears that the city had been paying up to the limit for some time past. In our description of the St. Louis reduction works (Nov. 1, 1894), it was stated that for the first 32 months of the contract the average amount of garbage treated was 90 tons per day, while the average for August, 1894, was 227 tons a day.

In the face of its own recent experience in delaying to relet until the last minute the contract for the borough of Manhattan (increase from $90,000 to $232,000 per year in price) the city of New York has not yet advertised the reletting of the contract for garbage disposal in the borough of Brooklyn, the present contract for which expires Dec. 31. It is altogether probable that this delay, like the previous delay in the case of the Manhattan contract, will prevent any real competition.

It is possible, however, that the city contemplates taking advantage of the situation in Brooklyn to experiment on its own account with methods of garbage disposal on a large scale. We have heard nothing to that effect further than an intimation in a report recently made to the Board of Estimate and Apportionment, by Mr. Jas. C. Bayles, that something of the kind has been mentioned.

The report by Mr. Bayles, just mentioned, advised the Board not to take steps to purchase the garbage reduction works at Barren Island. Mr. Bayles is of the opinion that garbage reduction is not a commercial success, and that burning such wastes at the several dumps on the water front would be the wiser ultimate plan for the city. In support of this conclusion he makes statements designed to show that the market for both grease and tankage from garbage reduction works is poor and unreliable, and that most of the garbage reduction works thus far built have been unsuccessful. Mr. Bayles' review of American reduction works is hardly a fair presentation of that side of the question, and he does not give a single fact to show that the art of garbage cremation is on any more satisfactory basis than garbage reduction. Nevertheless, we are not at all inclined to question his general conclusion that it would be unwise for the city of New York to buy the Barren Island plant, and we do most heartily endorse his suggestion that a careful investigation of the whole subject of garbage disposal should be made by the city as soon as possible. It is only fair to Mr. Bayles to say that he was merely called upon to report, within a limited time, and with inadequate data at hand, on the advisability of taking initial steps to buy the Barren Island works, and not on the broad question of garbage disposal generally.

It is of interest to note in this connection that even good old Boston is having trouble over garbage disposal matters. The city council of Boston has just passed an ordinance providing for the payment of $140,000 to its garbage disposal contractors for moving the reduction works from Dorchester to a more isolated site on Spectacle Island in Boston Harbor. This is the outcome of a vigorous crusade against the works by the people of the Dorchester section of the city, who have been clamoring for the removal of the plant ever since it was erected. It has been alleged that politics has had much to do with the crusade, which was particularly lively just before election a year ago, and did not result in definite action until just prior to this year's election. How this is we cannot say; but it would not be surprising or unprecedented if there actually were more politics than engineering in the agitation.

However this may be, it is an excellent illustration of the fact which experience has pretty well established, that a garbage disposal plant must be far removed from any residence section of a city or its suburbs, or it will at once become the object of organized attack, no matter how perfectly sanitary the process by which the disposal is effected.

From time to time during the past dozen years projects for high-speed electric railways have been heralded in the newspapers; and some of them have received more or less serious attention from engineers and capitalists. Thus far, however, no such railway has ever been put into actual operation; or has even reached the stage of actual construction; and with only two exceptions which we recall, nobody has ever made any actual experiments in the operation of electric railways at extremely high speed. The first of these exceptions was the experimental high-speed railway of David G. Weems, which was tested at Laurel, Md., in 1889 (Eng. News, Sept. 14, 1889). The second exception is the work now being carried on by German engineers on the Military Railway, from Berlin to Zossen, on which a motor car with accommodations for 50 passengers is to be run at a speed of 125 miles per hour.

Every such experiment, with the new problems it presents for solution, is of interest to engineers and worth placing on record; and we publish on another page an extended description of the installation which has been developed by a noted German electrical manufacturing company, written by one of the engineers in direct charge of the work. The experiment is an important one, not only on account of the high speed to be attained but because of the use of high-tension alternating current for the line transmission without either transforming it to direct current or reducing its potential in substations, which has heretofore been the practice. The designers of this road have taken the bold step of collecting current at 12,000 volts pressure directly from overhead wires along the track. This current is stepped-down in transformers located under the car, and is used in alternating current motors.

This is certainly heroic experimenting and highly interesting from the popular and spectacular point of view; but it appears to us to bear little more relation to practical commercial problems than the recent trial flights of dirigible balloons around the Eiffel tower. American engineers have had a larger practical acquaintance with high-tension alternating currents than the engineers of any other nation, and it is a case where familiarity breeds respect and not contempt. In this country we like to keep such currents at the top of a 30-ft. wooden pole; and the proposition to bring a row of three-phase high-tension conductors down within easy reach of a car roof is decidedly startling—especially when it is further proposed to collect the current and carry it through the car to transformers located underneath it. Such an installation may work all right on an experimental car; but that is no guarantee that safety could be secured in ordinary commercial operation. If one of these trolley wires should part and fall on the car roof the results might be very serious; and such occasional breakages can hardly be prevented. Even with the ordinary rolling contact, wear of the trolley wire is quite rapid on American street railways, and with a sliding contact such as the Germans have adopted, more rapid wear of the wire would, of course, be expected.

Moreover, even if the matter of safety could be provided for, the erection and maintenance of three lines of trolley wire, all of which must be kept a safe distance apart, is a proposition little likely to find favor in this country—especially when it is considered in connection with the use of six separate current collectors on top of the car. In these and numerous other details of the design of this high-speed car the reader must be impressed with the fact that the whole apparatus is exceedingly complicated and as a matter of course extremely costly. Now, it is still an open question how much the public is willing to pay for the privilege of riding at 100 miles per hour or faster. Probably it will not pay very much, and if a special high-speed railway is to be so costly in construction and maintenance that a large additional fare has to be charged, its chances of obtaining a paying traffic would appear to be pretty small.

THE ADAPTABILITY AND ECONOMY OF THE ROTARY KILN FOR BURNING PORTLAND CEMENT.

The paper on the rotary kiln process of cement manufacture, to which we give a large amount of space in this issue of Engineering News, is, by all odds, the best exposition of the theory and practice of this process which has ever appeared in print. It is not particularly gratifying to American engineers to be compelled to resort to the proceedings of a foreign engineering society for the best information respecting a manufacturing process which is distinctly a domestic development, but it must nevertheless be admitted that it is necessary in the present instance to do so. We are not going beyond the facts when we say that it has been exceedingly difficult in the past and is not yet easy for engineers to obtain anything like a scientific statement of the principles and

practice which mark the line between success and failure in the production of Portland cement by the rotary kiln process. It is doubtful, indeed, if the whole story has been told in the admirable paper which we lay before our readers this week. The manufacturers who have been at the pains and expense of developing the rotary kiln for burning cement have held, justly enough, that the practical knowledge which they have wrought out at the expense of toil and money was a personal asset in which others were not warranted in asking a share, and engineers who have made a specialty of designing rotary kiln plants have been scarcely more liberal with their information. These facts account in a large measure for the dearth of literature on the rotary kiln process of burning cement, and to them may be attributed probably some things that are lacking in the paper which we print elsewhere. The written and oral discussion which was brought out by the paper and which is in some respects quite as interesting and valuable will be printed in a succeeding issue. The following remarks, however, relate to both the paper and the discussion.

In one sense this paper may be considered a brief in favor of the general adoption of the rotary kiln for burning Portland cement. The argument presented is intended to prove, first, the economy of the rotary kiln and, second, its adaptability to raw materials of different varieties. The existence of these qualifications is evidently necessary if the rotary kiln is to claim serious attention from cement manufacturers; and that they do exist has to be proven practically entirely from the records of experience in the United States. These records, as presented in the paper which we publish and in other published articles, seem worthy of a brief recapitulation here.

It has been a common notion that the rotary kiln was adaptable only to certain kinds of raw materials. This notion originated partly in the failure of the original Ransome kiln to calcine the wet chalk and clay slurry from which the bulk of the English Portland cements are burned, and partly in the fact that its original success in America was with the dry raw materials of the Lehigh district in Pennsylvania. It was not until some years after the rotary kiln had proved its success with dry materials that it began to be seriously considered as a possibly successful method for burning wet mixtures.

As stated by Mr. Spackman, the first attempt to burn wet raw materials was made by Prof. Spencer B. Newberry at the works of the Warner Portland Cement Co., at Warners, N. Y., and later Prof. Newberry perfected the process at the works of the Sandusky Portland Cement Co., at Sandusky, O. Indeed, the Sandusky Portland Cement Co. ranks quite as high for its work in adapting the rotary kiln to wet materials as does the Atlas Cement Co. for its notable success in developing the same apparatus for calcining dry material. This fact deserves to be made prominent here, for the paper which we print elsewhere, it seems to us, gives scant credit to the labors of those who have made the notable success which has been reached in America with the rotary kiln using wet mixtures. This omission is particularly noticeable since, with the bulk of English manufacturers using wet materials, it would be supposed that American rotary kiln practice with wet materials would be of more direct practical interest than American rotary kiln practice with dry materials, as exemplified by the Atlas cement works.

Care should be taken not to fall into the error of thinking that the rotary kiln process is essentially a process involving the necessity of using a dry raw material. In America, rotary kilns are successfully used in burning both the dry mixtures of cement rock or clay and limestone and the wet slurries of marl and clay, and the development of the two is proceeding by nearly equal steps. What the ultimate result of the issue between wet and dry materials will be, is difficult to foretell. The earlier small plants using wet materials have not been notably successful nor have any of them grown to large proportions. On the other hand, the plants using dry materials have prospered to a remarkable degree, and have developed into enormous enterprises. The natural inference from this fact is that there are economies in the dry process which make it more profitable than the wet process.

It is apparent, however, that investors do not lay particular importance on this comparative lack of success of the wet process in the past, for some of the very largest cement plants now projected in the central states and particularly in Michigan, Indiana and Ohio, propose to use wet materials with rotary kilns. What their success will be only time can tell. The factors for and against their success, so far as they can at present be reduced to general principles, are probably quite accurately stated as follows: The older plants using the wet process have been small plants, and, other things being equal, a large plant will produce cement at a considerably less cost than a small one. This is a point in favor of the belief that the large wet process plants now projected will exhibit an economy superior to that shown by the small wet process plants of earlier construction. There seems to be considerable evidence to show that the fuel cost of production in rotary kilns is less with dry materials than with wet materials, which is the conclusion that would naturally be anticipated. The facts seem to indicate, furthermore that a much larger output per kiln can be obtained from dry materials than from wet materials. On the other hand, it is probably cheaper to prepare wet material for the kiln than it is to prepare dry material. Finally, there is no reason to suppose that the limit of economy has been reached by the rotary kiln with either dry or wet materials, and it is entirely possible that the limit of future economy in burning wet material is not so near at hand as it is in the burning of dry material.

So far, however, as the possibility of extending the use of the rotary kiln to the raw materials prevailing in England and the Continent is concerned, the question is not whether this kiln can be operated the more economically with a wet or a dry raw mixture, but it is whether it will burn either a dry or a wet mixture at less cost than it can be burned in the fixed intermittent or continuous kilns now commonly used in those countries. Some of the calculations made in the paper and discussion printed elsewhere indicate that with many of the materials used in Europe the rotary kiln may be expected to prove decidedly cheaper than the fixed kilns now in use. As the result of a comparative calculation, the authors of the paper figure a saving of nearly three shillings per ton by using rotary kilns, with the wet raw materials of the Thames and Medway districts in England, instead of the present fixed kilns. Mr. E. Candlot, the well-known French manufacturer, in his discussion on the paper, admits a saving due to rotary kilns of between 40 cts. and 60 cts. per ton. With American materials and under American conditions of labor and fuel cost the rotary kiln is decidedly more economical than any other form of kiln. Some calculations made by Mr. F. H. Lewis, M. Am. Soc. C. E., in 1898, give the following analysis of cost per barrel of cement made in rotary kilns and in continuous shaft kilns:

Cost per barrel.	Rotary kiln.	Continuous kiln.
Labor	2½ to 4 cts.	12 to 14 cts.
Fuel	11 to 15 cts.	5 to 6 cts.
Total	13½ to 19 cts.	17 to 20 cts.

In a great measure, however, the economy of the rotary kiln arises from other things than the saving in the kiln process alone. A rotary kiln will turn out from 125 to 150 tons of clinker per week as compared with 35 tons per week for the English chamber kiln and 70 tons per week for the Dietsch or the Schneider continuous shaft kilns. Stated another way, one rotary kiln will produce as much clinker as two continuous shaft kilns of the most efficient types, while the cost of construction, kiln for kiln, is in favor of the rotary kiln plant. Mr. F. H. Lewis, whose figures we quote above, estimates that the interest on the greater cost of the shaft kiln plant adds at least 1¼ cts. per barrel to the cost of the cement produced.

Another saving obtained by using the rotary kiln is in the cost of preparing the raw material for the kiln. All kilns except the rotary kiln require that the material shall be charged into them in the form of dry bricks or blocks. The cost of molding the mixture into the necessary forms, drying it and then charging it into the kilns is necessarily considerable. Indeed, so prominent an authority as Prof. Spencer B. Newberry considers that with the prevailing high wages in the United States the expense of preparing the raw mixture for the kilns would have prevented any considerable development of the Portland cement industry in this country, had not a method of avoiding these expensive operations been discovered in the rotary kiln process. With the rotary kiln, the wet slurry or the dry dust produced by the mixing process is run directly into the kilns without any expense for further preparation.

A similar saving is experienced in the handling of the clinker after it leaves the rotary kiln. In fixed kilns there is always a proportion of underburned bricks or lumps which have to be sorted out by hand before the clinker can proceed to the succeeding processes. Furthermore, the clinker comes from the kiln in large pieces which have to be crushed before it can be admitted to the grinding machinery. With the rotary kiln the calcination is so uniform that practically no underburned material exists, and the clinker comes from the kilns in granular form, the grains being about the size of a pea. No preliminary crushing is necessary to prepare this granular clinker to enter the grinding machines.

Finally, the fact that, with the rotary kiln, there is no interruption of the process to make the raw mixture into bricks and to charge them into the kiln and no sorting of the resulting clinker, has made it possible to substitute machine labor for hand labor to a degree which is impossible in plants using fixed kilns. To quote from the paper published elsewhere: "From the tipping wagons coming from the quarry to the final bags or barrels, the material is untouched by hand and passes automatically and continuously through all the stages needed to convert the rough limestone and shale into finely ground, sound and well-matured Portland cement." This automatic and continuous operation is characteristic not only of the particular plant referred to in the quotation, but of every modern rotary kiln Portland cement plant in America. In cement making, as in all other great manufacturing processes in America, fuel and power have been substituted for labor, with a substantial decrease in the cost of production, and, in cement making at least, with no loss but probably a gain in the quality of the product.

The influence of these co-ordinate economies, which are obtained where the rotary kiln is used, in conjunction with the saving in the cost of the calcination proper upon the success of the rotary kiln process, is generally well recognized by American cement manufacturers, but there are indications in the discussion of the paper which we publish elsewhere that its importance is not fully grasped by the English cement makers. In more than one instance the remarks made indicate that the speaker regarded the rotary kiln process as but little more than the substitution of a rotary kiln in the place of a fixed kiln, with little change in the process outside of the kiln house. As we have tried to point out, any such a belief indicates but a partial comprehension of the rotary kiln process as it exists in the United States. Another notion which crops out at intervals in the discussion is that the rotary kiln process is essentially a process for dry cement mixtures, or that, if it does operate with wet mixtures, there is some quality possessed by English wet mixtures which makes it less certainly applicable to them than to the wet mixtures used in America.

That the rotary kiln is capable of successfully burning wet raw materials has already been shown, and in the discussion which we print elsewhere, Mr. Spackman points out clearly that it burns successfully a great variety of both wet and dry mixtures. To summarize briefly, shale and limestone; limestone and soft clay; marl and clay; limestone and blast furnace slag; soda waste and clay, and calcareous earth are samples of the mixtures, which are being successfully burned in rotary kilns in the United States at the present time. It does not seem reasonable to suppose that the clays, chalks, marls and limestones of England and Europe should be more difficult to adapt to the rotary process. In fact we know on the

contrary that wherever the rotary kiln has been competently tried in Europe it has successfully burned the raw material furnished to it. For example, the Hemmoor Portland Cement Fabrik, near Hamburg, Germany, use rotary kilns to burn the chalk and clay materials of the Hamburg district, and obtain an average output of 200 tons of clinker per kiln per week, one of the largest records of output afforded by the rotary kiln anywhere in the world. At the Loller works in Germany a raw mixture of blast furnace slag and limestone is burned in rotary kilns with entire success.

This brief statement of the adaptability and economy of the rotary kiln may be very appropriately concluded with the following figures showing the growing popularity of this device in the United States. These figures are taken from the reports of the U. S. Geological Survey, and are as follows:

	No. of barrels produced—			No. of barrels produced—	
Year.	Rotary kilns.	Fixed kilns.	Year.	Rotary kilns.	Fixed kilns.
1893....	149,000	441,000	1896....	632,000	910,000
1894....	242,000	556,000	1897....1,311,000		1,366,000
1895....	400,000	589,000	1898....2,170,000		1,521,000

The figures for 1899, 1900 and 1901 are not available, but practically all new plants and all extensions of old plants have been designed to use rotary kilns, so that when these figures are available they will show that the shaft kiln is used in but a few of the smaller and older plants constructed before the rotary kiln had proved its success.

LETTERS TO THE EDITOR.

The Accident to the Steamer "Hudson."

Sir: Referring to Engineering News of Sept. 12, containing an article on accident to the steamer "Hudson" while on our railway May 28, 1901: I regret exceedingly to see a publication which is usually so ably edited permit a correspondent to insert such a very ridiculous and utterly impossible report of an accident.

In the first place, we had the ship in such a position that it was practically impossible to have put any shoring under her quarters. Secondly, the ship did not capsize at ebb tide, but at full flood, and had been the greater part of the time while on the ways with the tide 12 ins. lower.

We did not endeavor to right the vessel by carrying cables from the starboard side to the shore, as we knew when the vessel was pumped free of water she would right herself. As no cables were used to the shore to right the vessel, quite naturally, no wrecking steamer or tugs were used to right her. The opinion of any person (who could have the slightest claim to the title of expert) was (prior to the raising of the ship) that the ship had sunk.

The manner in which she was raised was: We employed the Merritt & Chapman Wrecking Co. by telephone three hours after the accident had happened. They immediately came to Baltimore, battened up the ship to stop all leaks and pumped the water out of the ship, when she righted herself without any assistance whatever. We then pulled her off of the railway.

The facts as to the cause of the accident are simply that the bonnet was taken off of the circulating pump at night (by employees of the steamship company) for the purpose of repairing it, and the thread of the Kingston valve leading to the pump was stripped, permitting the water to flow into the ship until she sunk low enough to bring her ash ports to the water, when she filled rapidly and sunk. In sinking she quite naturally capsized.

It is our opinion that the same accident would have happened to the "Hudson" had she been laying alongside her wharf. Yours truly,

The Wm Skinner & Sons Ship Building & Dry Dock Co. of Baltimore City.
Harry G. Skinner, Pres.

Baltimore, Md., Sept. 14, 1901.

(A copy of the above letter was submitted to the writer of the letter published in our issue of Sept. 12. In reply he states that the information was furnished him from a source which he supposed to be reliable, and that the cause of the vessel's capsize is a matter of controversy.—Ed.)

The Brooklyn Bridge Terminal.

Sir: In this week's issue you express surprise that the solution offered by the board of engineers for the improvement of the Brooklyn Bridge terminal was not thought of before. This solution is practically one-half of a scheme I published in the Brooklyn "Eagle" on Feb. 6, 1898, a copy of which I enclose. As you will see, I then proposed connecting the bridges at both ends making a double-track circuit, thus doing away with terminals entirely. It has always seemed to me that it is absurd for any railway to have expensive terminals in New York city, when the terminals could be placed out on Long Island and the stations in New York and Brooklyn could be mere stopping points. Yours truly,

T. Kennard Thomson.

Park Row Bldg., New York, Oct. 19, 1901.

(The copy of the "Eagle" accompanying the above letter shows a loop line connecting the present bridge and Bridge No. 2, running across City Hall Park and down Warren St. to West St., thence north on West St. to the foot of Canal St., and eastward on Spring and Delancey streets to Bridge No. 2. We are inclined to think, however, that the Center St. route for a loop line, recommended by the Board, would be preferable. A line on Center St. will closely parallel the Rapid Transit road on Elm St., the Fourth Ave. and Broadway surface lines, and will cross at two points the elevated and surface lines on Second and Third Aves. It will also land passengers close to the wholesale dry goods district, which is the destination of a large proportion of the travelers across the bridge.

In a more recent map submitted to us Mr. Thomson proposes a loop line leaving the bridge between Gold St. and Cliff St., and running south through the blocks to a subway line running westerly under Maiden Lane and Cortlandt St. to Washington St. It will then turn north and follow up West Broadway to Walker and Canal Sts., where connection would be made with Bridge No 3, as proposed by the recent Board of Engineers.

If some scheme like this last had been proposed and carried out when the bridge was opened for traffic nearly 20 years ago, it would undoubtedly have been of vast and permanent benefit. The enormous real estate damages which would be involved in such a scheme at the present day, however, place it quite outside the field of financial practicability.—Ed.)

Concerning the Proposed Increase of Dues in the American Society of Mechanical Engineers.

Sir: In the comparison of the dues of the various engineering societies in your issue of Oct. 3, I find an error in the case of the American Institute of Electrical Engineers. By the adoption of an amendment to the constitution May 21, 1901, the dues were fixed as follows: Entrance fee, $5; Associates, annual dues, $10, foreign, $5; members, annual dues, $15, foreign, $10; life membership, $200. As the above schedule did not go into effect until May 21, the change has not become generally known.

Yours truly, Ralph W. Pope, Secretary.

26 Cortlandt St., New York, Oct. 21, 1901.

Sir: I must say I do not like the tone of the letter you publish in the issue of Oct. 17, on the question of increasing the membership dues of the Mechanical Engineers, signed anonymously, "M. A. S. M. E." If this writer maintains that the society has not been managed wisely, tactfully, economically and always with the utmost regard for meeting the wishes of "the membership at large," I would wager he won't find one per cent. of the said membership in agreement with him. There has never yet been a time when the membership has been without "control of the society's management." On the contrary, the complete harmony among the members, the frictionless progress of the society as a body, and the subordination of its machinery to the scientific and commercial purposes for which it was established have made the Society of Mechanical Engineers conspicuous among its sister engineering societies. Never for a moment forgetting its dignity and importance, yet it has been managed in a truly democratic and progressive way, a way which has united its membership and made the society the great and permanent success it has become. Let us not have another breath of the spirit animating the letter of "M. A. S. M. E." enter into the debate on the questions at issue, as raised by your editorial.

You say: "Already the dues, we know, are such as to shut out from membership many [illegible] engineers." Who would care to hire an engineer [illegible]eak-minded that he begrudged paying out one per cent. of his salary for the honor and returns accruing from membership in this society? Is the society intended only for such? Does not his very income depend to a much larger extent upon his membership? If it doesn't, I would advise such a one to get out of the membership and remain out.

For my own part, I cannot feel that the question of raising the dues depends for its answer so much on the assumed poverty of the membership as upon the use to be made of the new revenue. Prof. Hutton states in his circular letter to the members that if the income be not increased the present benefits of membership must be reduced. He is upheld in this view by the Council and all the ex-presidents. The presumption, then, is that he states the fact, and that the members would prefer an increase of dues.

No one can possibly take exception to the obvious truth that all of the national engineering societies should use a union hall in which to hold annual meetings. But has anyone yet shown how this can be done? Will the civil engineers consent to an arrangement to allow the use of their audience rooms by other engineering societies? Surely, this has a very serious bearing on the question as to how much the dues must be raised. In fact, it is the vital point. George I. Rockwood.

62 Summer St., Worcester, Mass., Oct. 20, 1901.

(We may note respecting the last point raised by our correspondent, that the New York Railroad Club, which has for some years rented the auditorium in the Mechanical Engineers' house for its monthly meetings, held its first meeting this season at the Civil Engineers' house, and we believe is to use it for its meetings throughout the year.—Ed.)

The Report on the Physical Condition and Safety of the New York and Brooklyn Bridge.

Sir: Epitomizing the report of Engineers Duryea and Mayer upon "the physical condition and safety of the New York and Brooklyn Bridge," it clearly conveys, at least to engineers, the understanding that, first, the bridge in its present condition is fairly safe; second, that it can and ought to be made safer, and, third, that to prevent its deterioration now or hereafter the structure should have more systematic and intelligent care than it has had heretofore. A perusal of the painstaking report and its appendices shows that these conclusions are well supported by the facts and analysis given therein.

Although the general design of the bridge belongs to a past age, still the defects found are only those of details that can be readily remedied. The principal parts of the bridge, namely, the foundations, the masonry of the anchorages and towers and the crucible steel wire cables, are of excellent quality and workmanship, and as sound as they ever were.

It would not be worthy of the great, rich city of New York to tinker up the present structure in any cheap, makeshift way. The reconstruction should be more thorough than that suggested in the report; it should be radical and on modern lines. The old stiffening trusses and floor construction should be replaced by others of improved design; but the stays and suspenders near the towers should be kept. They can be made to work perfectly together in a statically determinate way. The anchor posts under the shore spans, suggested by the engineers, will be an essential feature of any reconstruction, as they will increase the rigidity and safety of the superstructure like no other device. The net result of a thoroughly well conceived reconstruction should be, first, and most important, a considerable reduction in dead weight; second, greater rigidity, vertically under moving loads and laterally against wind pressure; third, greater transportation capacity, and with it an increased margin of safety in towers and cables. All this can be obtained without greatly interfering with traffic over the bridge.

It is instructive to note from the report how some of the details peculiar to this bridge behaved, and it may not be amiss to comment upon the analysis therein of a few others.

(1) The appendix of the report has a section, "Stresses in Stiffening Trusses and Center Suspenders Due to Drop of Cables in the Center in Consequence of Rise of Temperature and Preponderate Moving Load on Main Spans." The calculation in that section takes account of the bending of the stiffening trusses in the middle span as caused simultaneously by the dropping of the cables under a uniform load and from high temperature, but it does not separate the stresses and deflection due to each of these two causes. There are rather large bending stresses caused by temperature changes alone in middle hinged stiffening trusses.* They should be combined with the maximum bending stresses, which, as we know, occur from unequal and not from uniform loading. Although they can in this instance occur only rarely, if at all, it is desirable for a better judgment of the maxima that the effects from the two causes should be stated separately. The bending and shearing strains will then appear to be somewhat larger than by the method given in the report.

(2) The assumption of points of contraflexure in the stiffening trusses of the main span is hardly justified by the facts. It is not mentioned in the report, and has perhaps been overlooked by the reporting engineers, that the stiffening trusses have adjustment joints in the top chords (but not in the bottom chords), two on each side of the tower in those portions held up by the stays. These joints consist of bolted splice plates, with elongated holes. Neglecting friction, they cannot transmit tensional chord strains. One of these joints is so near the last stay in each quarter as to make bending moments at

*See Appendix D to the Report of Board of Engineer Officers as to maximum span practicable for suspension bridges, 1894, p. 68 (Eng. News, Nov. 22, 1894); also article by Professor Melan in "Zeitschrift des Oesterr. Ingenieur and Architecter Vereins," Sept. 7, 1900, p. 553.

that point hardly large enough to influence noticeably the bending stresses occurring in the trusses between the last stay and the slip joint at the center of span. Prudence and the fact that the long stays lengthen considerably under load would seem to require us to lean to the more probable assumption of no point of contraflexure between the last stay and the center of the span. The result would be again bending and shearing strains in that part of the stiffening truss somewhat larger than those computed by the engineers.

(3) The worn condition of the slip joints in the end spans (located at the last stay) and in the middle span (located at the center) is not mentioned or considered, and yet it is they that cause the most frequent secondary stresses in the cables. The slip joints, in their present loose condition, appear to transmit little shearing stress from truss to truss. The larger part is very likely now transmitted through the suspenders at the joints to the cable in the form of bending stresses. They occur intermittingly from moving loads all day long, particularly in the main span, while the secondary stresses in the cable, discussed in the report, seem to be only those occurring gradually and at long intervals, and are therefore less dangerous.

(4) Another redundant stress in the cables is caused through their unequal heating by the sun. There is reliable authority for the fact that during the erection of the bridge, and before the superstructure was suspended, the finished cables would turn or twist at the center of the spans from morning to afternoon about 30°, as indicated by the positions of the clamps to which the suspenders were then not fastened. The heated wires, being longer, would seek a lower position, and the cooler wires, in the shade, being shorter, would rise to a higher position; hence the twisting of the cables. The cables, being prevented from twisting by the weight of the suspended structure, are exposed to inert strains, i. e., the wires will not all have equal tension, pointing to the necessity of protecting them against unequal heating.

(5) The report recommends long sleeves of cast-steel for the center of the cables to reduce the bending strains. This is easily a case where the cure may be worse than the disease. The sleeves, if tightly fitting, would simply remove the bending of the wires to two other spots, one at each end of sleeve. And if the sleeve be made so as to confine the bending of the wires to predeterminate fiber strains, then the sleeves cannot closely fit at the ends. Moisture could not be prevented from getting under them, either by condensation or by capillarity, exposing the wires to corrosion. It would be far better to leave the old wire wrapping on the cables and remove the principal cause of bending strains, namely, the slip joints in the trusses. The trusses should be continuous. Expansion can be provided for in other and harmless ways. The chords of continuous stiffening trusses will then serve also as chords for horizontal wind trusses. The present wind cables can be then left off and their weight entirely saved. It is doubtful whether they were ever of any use.

(6) The report also recommends the removal of the suspenders from that portion of the stiffening trusses which they now hold up in conjunction with the stays. That plan would be objectionable, in that it would make first the curvature of the cables sharper at the center of each span and aggravate the trouble from bending; and, next, it would deprive the bridge of that rigidity in the quarters which it now unquestionably has as the effect of the interlacing of the suspenders with the stays, a feature that at least in this bridge works very well. Without it, the oscillations in the long stays and quivering of the structure could hardly be prevented. As remarked before, it is perfectly practicable, with proper details, to make the suspenders and stays work together in carrying statically predetermined ratios of the load, and thus remove the present uncertainty of load distribution in them.

(7) The suggestion is made in the report for the improvement of the bridge of putting vertical anchors under the shore spans near the stay system. It is therein stated that the idea of the anchorage itself is an old one, having been suggested for this bridge before and being a feature of one of the designs for a bridge over the Hudson River. The latter clause evidently refers to my design for the North River bridge. I am not aware that it was originated or suggested before I used it in the suspension bridge over the Allegheny River at Seventh St., in Pittsburg, built in 1884. At one end of this bridge the anchorage is placed a considerable distance back from the river, because of intervening railroad tracks. Anchor posts are here placed at about one-third the span from the anchorage. It is the first instance of their use, as far as I know.

The writer's first design of the North River bridge, in 1887, shows anchor trestles under the middle of each shore span. It was at first proposed to have elevators in them to the streets underneath, but the later design shows simply anchor posts.

That plan prompted, in 1888, the late A. M. Wellington to suggest, with the writer's knowledge, a similar arrangement in connection with his proposal to enlarge the traffic facilities of the Brooklyn Bridge. This is the only occasion when such a plan was suggested for the Brooklyn Bridge before. Although a sufficiently obvious expedient now for long shore spans, it was novel when the writer first used it. It would be efficient for the strengthening of the Brooklyn Bridge, but the same may not be said of the other devices recommended in that connection in the report.

(8) It should be remarked that wire cables can endure without permanent injury more abuse, including secondary stresses, than any other metal member of a bridge. This is aside from the fact that they should nevertheless be avoided, if possible. I may instance the old Smithfield St. Bridge, in Pittsburg, rebuilt by me in 1881. In that bridge the iron wire cables had been subjected for many years to excessive bending stresses, in addition to excessive tensional stresses, frequently per day exceeding half of their ultimate strength. Yet on testing the wire showed no diminution of strength or elasticity. The wires had not even lost the original set they had on the wire drums before they were put into the cable, 34 years previously. A similar experience was had with the wire from the cables of the old Niagara railway suspension bridge.

In view of that experience, it can be said with confidence, that the strength of the steel wire cables of the Brooklyn Bridge has not been impaired. It is known that they were made with great care, so that all the wires have normally equal tension. It is also known that the ultimate strength per square inch is greater than 160,000 lbs. (that assumed in the report) by at least 6%. Corrosion is their deadliest enemy, and if it should be allowed to set in, in the saline atmosphere of this city, its baleful effects, eating into the interior of the cable, would be well nigh incurable. Whatever be done, the cables should be kept thoroughly painted; they show many bare places now.

Gustav Lindenthal.

New York city, Oct. 19, 1901.

Notes and Queries.

E. M., Havana, Cuba, desires the address of manufacturers of solid and hollow cement blocks for building purposes.

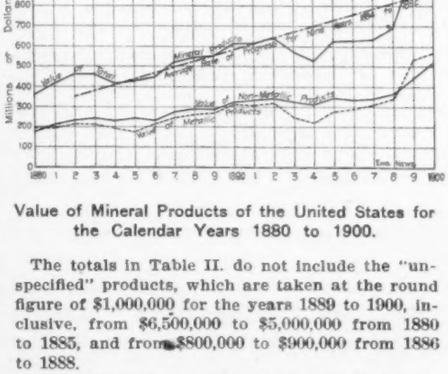
J. L. S., Indianapolis, Ind., asks what the difference in volume is between slushed gravel, such as is discharged from a centrifugal pump, and loose gravel measured in wagon loads.

We know of no data upon the subject and should think that the shrinkage of gravel by wetting would vary more or less with different kinds of gravel.

H. H., St. Louis, Mo., wants the address of manufacturers of fiber extracting machinery suitable to extract fiber from the aloe plant. He has heard that the "Todd" machine, used in the Bahamas, does this work satisfactorily, but he does not know the address of the makers.

STATISTICS OF MINERAL PRODUCTS OF THE UNITED STATES.

The Division of Mineral Resources of the U. S. Geological Survey has issued a large chart containing tables of the quantities and values of the mineral products of the United States for the calendar years 1891 to 1900, inclusive. The figures for the year 1900 are given in Table I., while Table II. gives the total values of the metallic and non-metallic products for the 21 years, 1880 to 1900, inclusive.



Value of Mineral Products of the United States for the Calendar Years 1880 to 1900.

The totals in Table II. do not include the "unspecified" products, which are taken at the round figure of $1,000,000 for the years 1889 to 1900, inclusive, from $6,500,000 to $5,000,000 from 1880 to 1885, and from $800,000 to $900,000 from 1886 to 1888.

The figures given in Table II. we have plotted in the accompanying diagram. It shows clearly the falling-off in the value of mineral products in the period of slight financial depression, 1884 to 1886, the great falling-off in the period of severe depression, 1893 to 1897, and the extraordinary increase in the years 1899 and 1900.

The figures of values for these last two years are due partly to increase of price and partly to increase of tonnage. If the products of the year 1900 had been valued at the prices per ton per barrel, etc., which prevailed in the period of low prices the total values would be at least $200,000,000 lower than those given in the table.

From 1884 to 1892, the rate of progress in values was nearly constant, as shown by the in-

TABLE I.—Mineral production of the United States for the Year 1900.

	Quantity.	Value.
Metallic.		
Pig iron (spot value),[1] long tons[2]	13,789,242[2]	$259,944,000
Silver (coining value)[4] Troy ozs.	59,610,543	77,070,471[4]
Gold (coining value),[5] Troy ozs.	3,837,215	79,322,281
Copper,[6] value New York, lbs.	606,117,166	98,494,039
Lead, value at N. Y., short tons[7]	270,824	23,561,688
Zinc, value at N. Y., short tons.	123,886	10,654,196
Quicksilver, San Francisco) flasks[8]	28,317	1,302,586
Aluminum, value Pittsburg, lbs.	5,200,000	1,716,000
Antimony,[9] short tons	1,750[9]	346,980
Nickel,[10] at Philadelphia, lbs.	9,715	3,886
Tin, lbs.	.....	.....
Platinum, (crude),[9] Troy ozs.	400	2,500
Total value metallic products		$552,418,627
Non-Metallic (Spot Values).[1]		
Fuels:		
Bituminous coal,[11] short tons	212,513,912	$221,133,513
Penn. anthracite, long tons	51,221,353	85,757,851
Natural gas,	.....	23,606,463
Petroleum, bbls.[12]	63,362,704	75,752,691
Structural materials: Brick clay	.....	12,000,000
Cement, bbls.[13]	17,225,131	13,279,167
Stone.[14]	.....	47,958,539
Abrasive materials:		
Corundum & emery, shrt tns	4,305	102,715
Garnet (abrasive purposes).‡	3,185	123,475
Grindstones	.....	701,121
Infusorial earth and Tripoli‡	3,615	24,207
Millstones	.....	32,858
Oilstones, etc., lbs	.....	181,011
Chemical materials:	1,602†	170,036
Borax, tons	24,235§	848,215
Bromine, lbs.	521,444	140,790
Fluorspar, short tons.	18,450	94,500
Gypsum, short tons.	594,402	1,627,203
Marls, short tons.	60,000	30,000
Phosphate rock, long tons	1,491,216	5,359,248
Pyrite, long tons	204,615	749,991
Salt, bbls.[15]	20,869,342	6,944,603
Sulphur, short tons	3,525	88,100
Pigments: Barytes (crude).‡	67,686	188,089
Cobalt oxide, lbs.	6,471	11,648
Mineral paints, short tons.[16]	72,222	881,393
Zinc white, short tons ‡	48,840	3,667,210
Miscellaneous: Asbestos, shrt tns	1,654	16,310
Asphaltum, short tons	68,429	491,598
Bauxite, long tons	23,184	89,676
Chromic iron ore, long tons.	140	1,400
Clay (other than brick), tons	.....	1,840,377
Feldspar, short tons	21,353	173,659
Fibrous talc, short tons.	63,500	499,500
Flint, short tons	32,495	179,351
Fuller's earth, short tons.	9,698	67,535
Graphite, lbs	5,507,855‡	197,579
	611‡	
Limestone (fluxing) long tons	7,495,435	4,500,000
Magnesite, short tons.	2,252	19,333
Manganese ore, long tons.	11,771	100,289
Mica, lbs.	456,393a	92,758
	5,453b	54,302
Mineral waters, galls., sold.	47,558,784	6,245,172
Monazite, lbs.	908,000	48,805
Ozocerite, refined, lbs.	.....	.....
Precious stones	.....	233,170
Pumice stone, short tons.	.....	.....
Rutile, lbs.	300	1,200
Soapstone, short tons	27,943	383,541
Total value non-metallic products		$516,690,262
Total value metallic products		552,418,627
Estimated value unspecified[17]		1,000,000
Grand total		$1,070,108,889

*Value at San Francisco. †Short tons. ‡Refined. §Crude. ‖Crystalline, lbs. ‡Amorphous, tons. a Sheet mica, lbs. b Scrap mica, tons.

[1]Value at the point of production. [2]Long tons 2,240 lbs., short tons 2,000 lbs. [3]Iron ore production in 1900, 27,553,161 long tons; value at mines $66,590,504. [4]$1.2929 per ounce Troy. [5]$20.6718 per ounce Troy. [6]Including copper from imported pyrites. [7]The product from domestic ores only. [8]76½ avoirdupois lbs. net. [9]Includes antimony smelted from imported ores in 1899, 83%. [10]Including nickel in copper-nickel alloy, and in exported ore and matte. [11]Including brown coal and lignite, and anthracite mined elsewhere than in Pennsylvania. [12]Of 42 gallons. [13]Of 300 lbs. for natural cement, and 400 lbs. for artificial Portland. [14]Not including limestone for iron flux, or grindstones. [15]Of 280 lbs. net. [16]Including metallic paints, ocher, umber, Venetian red, sienna, ground soapstone, ground slate and mineral black. [17]Including building sand, glass sand, iron ore used as flu.. in lead smelting, tin ore, nitrate of soda, carbonate of soda, sulphate of soda, and alum clays used by paper manufacturers.

TABLE II.—Value of Annual Mineral Product of the United States from 1880 to 1900.

Year.	Products—Metallic.	Non-metallic.	Total.
1880	$190,039,865	$173,279,135	$363,319,000
1881	192,892,408	206,783,144	399,675,582
1882	219,755,109	231,340,150	451,095,259
1883	203,128,859	242,812,219	445,941,078
1884	186,109,599	221,879,506	407,989,105
1885	181,586,587	241,312,093	422,898,680
1886	214,897,825	230,088,769	444,986,594
1887	248,925,054	270,989,420	519,914,474
1888	253,731,822	286,150,114	539,881,936
1889	267,247,033	282,623,812	549,870,845
1890	305,735,670	312,776,503	618,512,173
1891	300,232,798	321,767,846	622,000,644
1892	307,716,239	339,958,842	647,675,081
1893	249,981,866	323,325,620	573,307,486
1894	218,168,788	307,455,351	525,624,139
1895	281,913,639	338,345,361	620,259,000
1896	287,596,906	333,936,110	621,533,016
1897	302,108,502	327,655,427	629,853,979
1898	343,400,217	353,802,130	697,202,347
1899	525,472,243	445,428,651	970,900,894
1900	552,418,627	516,690,262	1,069,108,889

clined straight line drawn through the broken line corresponding to the total values for these years. Continuing this line to the year 1900 it shows the extent of the depression of the years 1893 to 1898, and the extent of the increase for the years 1899 and 1900. If the prices of these last two years had been normal instead of boom prices, the plotted line of total values would have fallen about to this straight line, which may therefore be taken as indicating the average rate of progress for the last 16 years. It indicates a rate of increase of about 70% in a decade, or a little over three times the rate of increase of population.

A BRIDGE IS TO BE BUILT IN COSTA RICA, says the New Orleans "Times-Democrat," which will be 700 ft. long and 360 ft. above the water level. It will be on a line of railway now being constructed by Snyder & Bartell, of New Orleans. No details are given, other than to say that it will be of the cantilever type.

OIL-BURNING SYSTEMS FOR LOCOMOTIVES.

Several railways on the Pacific Slope have of late years been using oil fuel quite extensively, and the development of oil wells in Texas has led to the introduction of this fuel to some extent in that State. Particulars of tests made with Texas and California oils by Mr. Howard Stillman, Engineer of Test of the Southern Pacific Ry., were given in our issue of July 11. Various forms of burners and firebox arrangements are used, and recent experiments made with the W. N. Best oil-burning system appear to have given satisfactory results, with an economy in fuel expenses, while there is also said to be a saving in repairs to boiler tubes. The system is claimed to have several advantages over other oil-burning systems, especially in causing little or no smoke or smell, even with the Texas oil, which contains considerable sulphur. One locomotive has made a monthly average of 52.8 miles per 200 gallons of Texas oil, while the average mileage with other burners is said to be 28 to 40 miles. With California oil the Best system is claimed to make 170 gallons of oil equivalent to 2,000 lbs. of coal, as compared with 200 gallons for other burners.

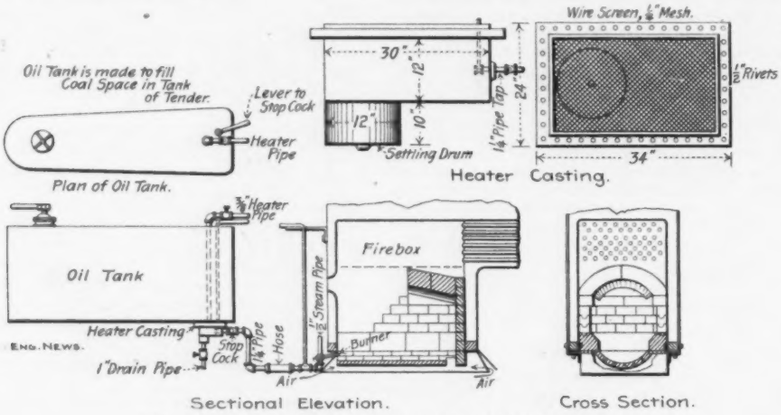


FIG. 1. OIL-BURNING SYSTEM FOR LOCOMOTIVES.
W. N. Best and W. A. Cooper, Patentees, Los Angeles, Cal.

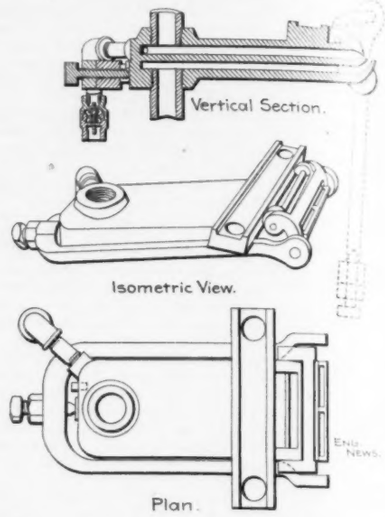


Fig. 2. Details of Oil Burner for Locomotives.

Fig. 1 shows the general arrangement of the apparatus. The firebox is lined with firebrick, and has an arch and invert floor of the same material, the latter taking the place of the grates. For the firebrick a life of six months is claimed. The burners are placed at the bottom of the back end of the firebox, with hose connections to a pipe from the oil tank, which is made to fit in the coal space of the tender. One of the features of this system is that a heater under the tank renders the oil fluid before it goes to the burner. From the boiler a ⅜-in. steam pipe is led to the heater, and a ½-in. steam pipe leads to the burner to spray the already heated oil into the firebox. Air enters at both ends of the ashpan, as shown. Fig. 2 shows in detail the form of the burner. Fig. 3 shows the burner and furnace arrangements for stationary boilers. In the burner the steam aperture is aboye that for the oil, and the arrangement is such as to thoroughly atomize the oil and provide complete combustion.

In experiments made with a passenger engine (No. 102) and train on the International & Great Northern Ry. three trips from Palestine, Tex., to Longview and return were made on Sept. 1, 2 and 3, the engine consuming 19, 19½ and 18 barrels of crude oil on the respective trips. The following is an extract from the report of the trips as made by Mr. W. N. Best to Mr. F. Hufsmith, Superintendent of Motive Power and Rolling Stock:

The train consisted of the average number of cars: 2 Pullmans, 1 chair car, 1 smoking car, 2 baggage cars and 1 mail car; 7 cars in all. Total distance in each round trip, 162 miles. At all times we had abundance of steam on the highest grades, and last evening on Palestine Hill, with 9 coaches, the pop-valve was blowing off steam.

Average amount of coal consumed to make the same run with same train, 7½ tons at $3.75	15,000 lbs.	$28.12
Crude oil, 19 barrels at 60 cts.	5,985 "	11.40
Difference in favor of oil	9,015 "	16.72

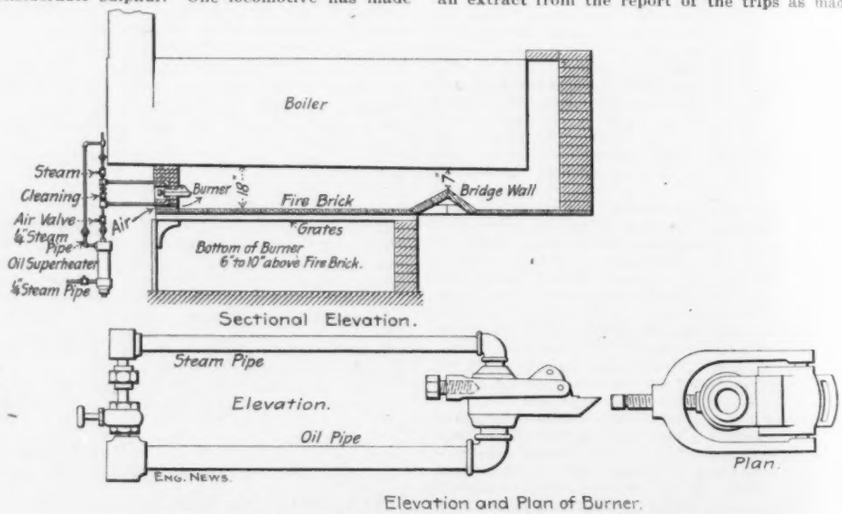


FIG. 3. OIL-BURNING SYSTEM FOR STATIONARY BOILERS.

THE HEIGHT OF WAVES AT SEA was the subject of a paper presented to the British Association at its last meeting by Mr. Vaughan Cornish. He quotes the following as the average height in feet of ocean waves in deep water, far from land, as obtained by several independent observers:

	Desbois.	Paris.	Wilson Barker.	Mean.
Hurricane	28.54	25.43	28	27.32
Strong gale	20.84	19.57	23	20.07
Gale	15.42	....	14	14.71
Strong breeze	10.83	....	8	9.42

The author observed, during gales in the North Atlantic, waves of a larger size recurring at short intervals; and these were the dangerous waves, and the ones usually estimated by seamen at 40 to 50 ft. He thought it would be well hereafter to record the ordinary maximum wave as well as the average. He gave no record of maximum waves from the observations of himself or by others.

CANADIAN SPRUCE FORESTS, says Mr. J. C. Langelier, Superintendent of Forest Rangers of Quebec, will supply the world's demand for pulp wood alone for 840 years, on the basis of 1,500,000 tons annually of manufactured pulp. The latter amount is equal to about the present total annual production of the United States. The extent of the spruce forests remaining untouched in the four provinces is given as follows: Ontario, 52,818,420 acres; Quebec, 144,363,454; New Brunswick, 11,224,540, and Nova Scotia, 10,853,544 acres. Out of over five billion feet board measure of spruce timber consumed for all purposes in 1900, 130,400,000 ft. B. M. represented pulp wood; and of this 30% was exported to the United States.

THE RAILWAYS OF NEW SOUTH WALES, Australia, aggregated 2,845½ miles on June 30, 1901, and the capital cost then amounted to $194,633,905, according to the report of the Railway Commissioners for the year ending June 30, 1901. The traffic and revenue showed a material increase, and the operating expenses also increased, but in less ratio. After paying operating expenses, and providing a sum of $7,124,700 for interest on the railway capital at 3.66%, the surplus was $528,190. About 565 miles of pioneer lines are now under construction. Steady progress is being made in the interlocking of switches and signals, and in the introduction of safety appliances generally. New locomotives and cars have been added to the equipment, valued at $530,435. Grade improvements are being carried out, and some of the structures have been renewed. The net returns per mile of line were $2,775, the operating expenses being $3,675. The total operating expenses aggregated 57.17% of the earnings as compared with 66.69% in 1888. The street and suburban railways operated by the Commissioners, which use electric or steam traction, aggregate 79¼ miles, and electric motors are superseding the locomotives. On these lines the operating expenses consume 83.83% of the earnings. The operating expenses per car mile are about 29 cts., while the net returns are 6 cts.

on the same railway a 90-ton ten-wheel freight engine (No. 215), with cylinders 20 × 28 ins., has also been equipped with this system. In August, after the crew had become expert in the handling of fuel oil, Mr. Best reported that a trip from Palestine, Tex., to Houston and return, 308 miles, was made with 56¼ barrels of oil (17,640 lbs.), while the coal consumption, based on the performance sheets of similar engines, would be 17¾ tons (35,600 lbs.). On a run of 100 miles 26½ barrels of oil were consumed, which, at 60 cts. per barrel, represented $15.90. The same run would have required about 7 tons of coal, at $3.75, or $26.25. This showed a saving of $10.35 in favor of the oil fuel. With oil fuel the engine ascended a heavy grade at 20 miles an hour with the pop valve blowing, although the two injectors were at work, the reversing lever full over and the throttle valve wide open, showing complete combustion and good steaming capacity.

This oil-burning system has been patented by W. N. Best and W. A. Cooper, 217 Stimson Building, Los Angeles, Cal., and we are indebted to them for information made use of in the above article.

SEPTIC TANK AND DOUBLE CONTACT FILTER BEDS FOR TREATING THE SEWAGE OF GLENCOE, ILL.

By H. D. Wyllie.*

WORKS.—The works shown by Figs. 1 and 2 were recently put in operation at Glencoe, Ill. They are designed to serve a population of 600, the maximum flow of sewage and storm water provided for being 25,000 gallons per day. They consist of one grit chamber, one septic tank and four high and four low-level aerating bacterial filters, all of which are built in concrete.

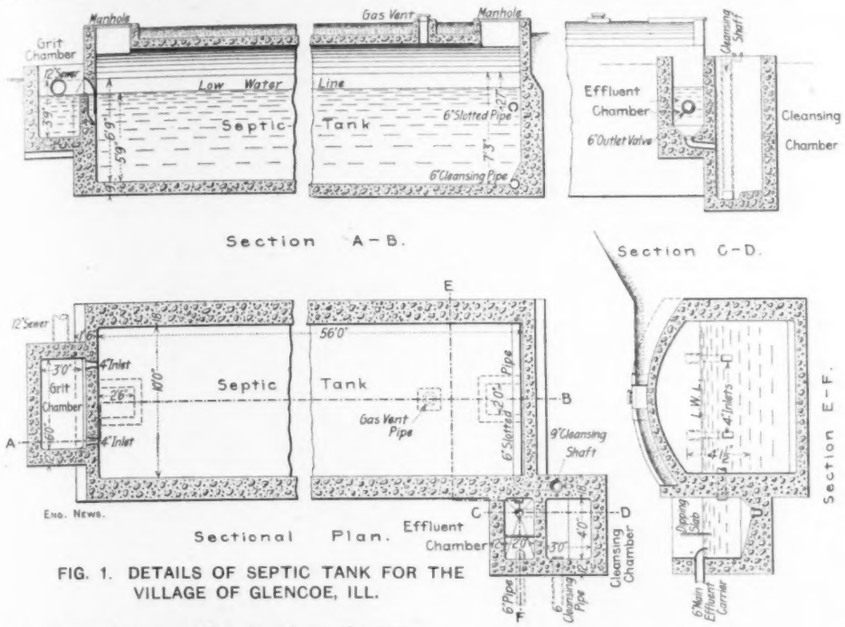


FIG. 1. DETAILS OF SEPTIC TANK FOR THE VILLAGE OF GLENCOE, ILL.

GRIT CHAMBER.—The main outfall sewer discharges into the grit chamber, shown in Fig. 1, which is 6 × 3 ft. × 4¾ ft. deep. From this chamber two channels lead off to the tank, into which the sewage is delivered by two special inlet pipes about 3 ft. below the springing.

SEPTIC TANK.—The tank, Fig. 1, is 56 × 10 ft. × 6¾ ft. deep below the spring line. It is covered with a concrete arch, over which a layer of soil is spread. Access to the tank is provided by two manholes, with sealing covers, but these are not intended to be opened except for the purpose of inspection.

In the tank the solids present in the sewage are separated and retained, and the organic matter is acted upon by the liquefying micro-organisms present, by which it is broken down into simpler substances, capable of being dealt with by filtration. The effluent, thus freed from solids in suspension, passes off through a slotted cast-iron pipe, laid horizontally across the end of the tank 2¼ ft. below the spring line, into the effluent collecting channel.

Any mineral detritus which may escape from the grit chamber, together with the insoluble residue from the sewage solids, accumulates slowly in the tank. A similar tank has been in use in Exeter, England, for over five years without such an accumulation of deposit as to require removal. It is, therefore, not expected that the deposit in the tank at Glencoe will need to be removed except at very long intervals. In order that this may be done when necessary, without draining off the liquid contents, a slotted pipe is constructed across the end, at the bottom of the tank, from which a 6-in. pipe leads to the cleansing well. By opening a valve in the latter, the deposit from the end of the tank may be drawn off. The deposit which is banked against the end of the tank being thus removed, the remainder should be left until it in turn drifts forward.

The effluent chamber, 2 × 4 ft. in plan, is constructed as shown by Fig. 1, and the tank effluent passes therefrom by the main effluent carrier to the admission valve chambers of the filters.

FILTERS.—The four high-level filters, shown in plan and section by Fig. 2, are each 17 ft. 10½ ins. × 14 ft. The dimensions of the low-level filters are slightly greater to compensate for the area taken from them by the gear chambers. They are filled to a depth of 4 ft. with furnace clinker, broken to pass through a ½-in. screen and freed of dust.

The tank effluent is distributed over each filter in turn by lines of 6-in. stoneware channels, laid on the top of the filtering material, and fed by a main distributor 6 ins. in diameter. The filtered effluent is collected by lines of 3-in. agricultural drain pipes, laid on the filter floor, and discharging into a stoneware main collector 6 ins. in diameter.

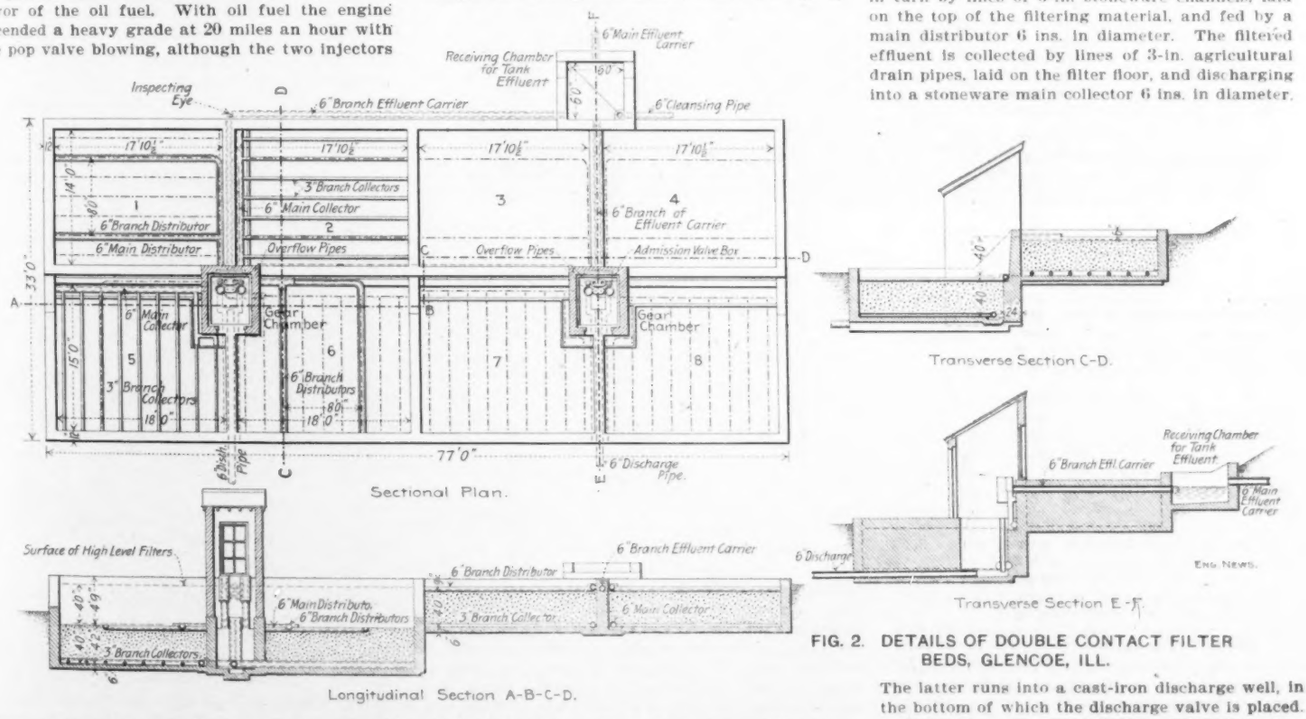


FIG. 2. DETAILS OF DOUBLE CONTACT FILTER BEDS, GLENCOE, ILL.

The latter runs into a cast-iron discharge well, in the bottom of which the discharge valve is placed.

METHOD OF WORKING FILTERS.—The high-level filters are filled in turn, each being kept full while the next is filling. The effluent discharged from each upper filter goes on to the lower filter immediately adjoining it, and the low-level discharge valves are connected to the shaft of the upper gear, so that the whole works together.

*General Manager, Cameron Septic Tank Co., 303 Dearborn St., Chicago, Ill.

The effluent remains in the filter for a period of from four to six hours, during which time the impurities present in solution are oxidized by the bacteria attached to the surfaces of the filtering medium. The discharge valve is then opened, and the filtered effluent escapes, drawing down after it a supply of air into every crevice of the filter. The latter drains and aerates while the remaining filters of the set are filling, after which it is again filled. This method of working renders the filters self-cleansing, so that they retain their purifying power unimpaired.

AUTOMATIC ALTERNATING GEAR.—The filling and emptying of the filters is effected automatically by means of the alternating gear. As soon as a filter is filled, a small quantity of filtered effluent overflows from its discharge well into its actuating bucket, thereby causing the closing of its admission valve, and, after the proper interval has elapsed, the opening of its discharge valve, and the release of the contents of the filter.

ATTENTION REQUIRED.—An installation on similar lines has been at work at Exeter, England, for over five years, the only attention it has required having been to oil the bearings every few weeks and loosen the surface of the filters at long intervals, when these have become compacted.

The operation of the purification works may be briefly summarized as follows: The whole of the impurities of the sewage, both solid and liquid, is destroyed by the combined action of the tank and filters without the aid of chemicals, labor or machinery, and without the production of sludge. The works being automatic throughout, and the workings of the filters in particular being controlled by apparatus of proved reliability, there is no risk of such temporary breakdowns as occur where the working of an installation is dependent upon the fidelity and vigilance of an attendant. Moreover, the tank being entirely covered in, and there being no screenings or sludge to remove from the works, there is no possibility of a nuisance arising therefrom.

FIG. 3. VIEW OF THE SEWAGE DISPOSAL WORKS AT GLENCOE, ILL.

THE CHICAGO & JOLIET ELECTRIC RAILWAY.

The new electric railway between Chicago and Joliet was officially opened Sept. 25, as already noted in our columns, a party of some 300 invited guests from the two cities and from towns along the route being taken over the line in special cars and entertained at a luncheon in the grand stand of the Joliet race course. The line is owned by the Chicago & Joliet Electric Ry. Co. and the Chicago & Des Plaines Valley Electric Ry., which are related corporations, controlled (through the ownership of their stock) by the American Railways Co., of Philadelphia, Pa., which is financiering a number of interurban electric railways. This company also controls the stock of the Du Page Construction Co., which built the road.

The line extends from the Chicago city limits at Archer Ave. to the Court House at Joliet, a distance of 31 miles. At Chicago connection is made with the Archer Ave. line of the Chicago City Ry., but no through cars are run into the city. At Joliet the cars pass over the lines of the existing electric railway. A branch is under construction from Summit to the village of Lyons, and an extension to Aurora, Ill., is projected.

The route is partly through an agricultural and quarry country, and partly through a rolling wooded country which, in spite of being accessible only by teams, has long been a favorite region for excursions and picnic parties, so that a large traffic of this class is in sight. Local traffic along the line is already being developed, as the hourly service of through cars in both directions, in addition to cars running shorter distances, is much more convenient than that of the steam railway, besides which the cars pass through the main streets of the towns, and thus take up and set down passengers close to their destination. The fares are lower than on the railways—40 cts. single trip, or 32 cts. if a book of tickets is purchased. This is exclusive of the 5 ct. fare on the connecting cars of the Chicago City Ry.; but this fare, with transfers, enables passengers to reach almost any part of the city. The schedule time is about 1 hour 45 minutes from Joliet to the city limits, but this is expected to be reduced to 1 hour 20 minutes, making about 1 hour 45 minutes to the business district of Chicago. The speed is as high as 25 to 30 miles an hour at times, the maximum speed being 40 miles per hour.

The line is largely double track, built on its own right of way, but there is some single track alongside of the public road. It parallels the line of the Chicago & Alton Ry. for a part of the distance. The grades and curves are as a rule easy, but there are maximum grades of 5% (400 ft. long) going north, and 4% (200 feet long) going south. The sharpest curve outside the city of Joliet is one of 150 ft. radius near the northern limits of the village of Lockport. The very sharp curves are protected by check rails. There are a few plate girder bridges, and also some culverts, retaining walls, etc., built of the local limestone. Outside of the towns and villages the track is laid with 70-lb. T rails of the Am. Soc. C. E. section; 60-lb. 6-in. T rails are used in Joliet, and 73-lb. 7-in. girder rails in Lockport and Lemont. The 70-lb. rails are laid with broken joints, spliced with six-bolt angle bars, and fitted with the protected copper bonds, 9 ins. long under the angle bars. There are 15 ties to each 30-ft. rail length, and the line is ballasted with broken stone. On the private right of way the rails are left exposed, but in the road a paving of limestone screenings is filled in between and outside of the rails. The single track portions of the road are being equipped with automatic electric signals.

The cars are all of the double-truck pattern, and were built by the J. G. Brill Car Co., of Philadelphia, Pa. Each car has two compartments and a toilet room. In some of the cars both compartments have the seats arranged as in railway cars, one compartment being a smoking room. In other cars one compartment is for baggage and express matter, and has side seats. Each car is equipped with the Christensen air brake and an air whistle instead of a gong, while there is a liberal supply of electric lamps, including powerful electric headlights. Each car has four electric motors of 40 HP., one on each axle, geared for a speed of 40 miles per hour. The cars are 48 ft. long and 9 ft. wide, and seat 50 passengers. They weigh about 26 tons loaded.

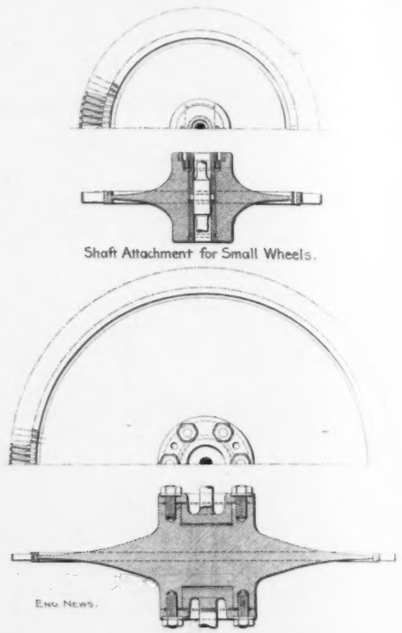


Fig. 1. Wheel of the De Laval Steam Turbine: The De Laval Steam Turbine Co., New York, Makers.

Power for operating this railway is furnished from the water power and electric generating plant of the Economy Light & Power Co. at Joliet. This is transmitted to a main station at Joliet, and thence to two substations at Lemont and Summit. The Joliet station has three units, each consisting of an induction motor and a direct-connected continuous-current generator of 250 K. W. There is also a storage battery of 400 K-W. capacity at hour rate. The induction motor is of 360 HP., with a current of 2,200 volts, 85 amperes. The generator delivers a current of 550 volts at no load, or 600 volts at full load. The Summit substation has two motor-generator sets similar to the above, and a storage battery of 300 K-W. capacity. The Lemont substation has one motor-generator set similar to the others, and a storage battery of 300 K-W. capacity. The current is delivered at the Joliet station at 3,300 volts, sent out at 15,000 volts to the other substations, and transformed down

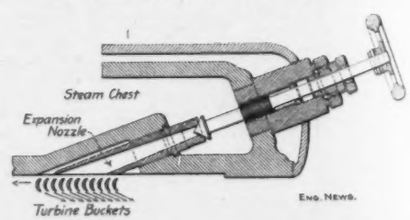


Fig. 2. Buckets and Steam Nozzle of De Laval Steam Turbine.

to 600 volts for the trolley wire. The trolley wire is in general carried by span wires between side poles, but on part of the line center poles with brackets are used. All the electric plant and equipment were supplied by the General Electric Co., of Schenectady, N. Y. The substations and car sheds are not yet fully completed.

Mr. F. E. Fisher, of Joliet, is the Manager of the road, and Mr. A. S. Kibbe, Jun. Am. Soc. C. E., of Philadelphia, Pa., is engineer for the American Railways Co.

THE DE LAVAL STEAM TURBINE.

In describing the machinery exhibit at the Paris Exposition in our issue of Aug. 16, 1900, we made brief allusion to the De Laval steam turbine, but gave no further description of it. In the last three or four years this machine has been consid-

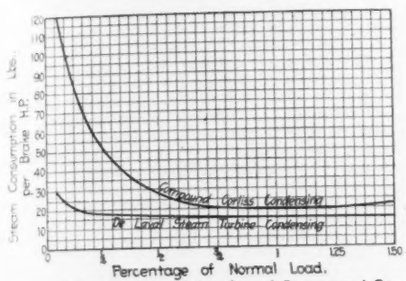

Steam Consumption in Lbs. per Brake H.P.
Compound Corliss Condensing
De Laval Steam Turbine Condensing
Percentage of Normal Load.

Fig. 4. Comparative Efficiencies of Compound Condensing Engine and De Laval Steam Turbine.

erably improved in construction, and some new applications have been made. An extensive plant has been erected during the past year at Trenton, N. J., for the manufacture of the De Laval turbine for the American market, and for this reason a short description of some features of the mechanism may be of interest.

This steam turbine consists of a narrow wheel, shown diagrammatically in Fig. 1, having buckets or vanes formed on its outer surface, the wheel running in an outside casing. The buckets are of a crescent-shaped cross-section, being set with their longer direction parallel to the axis of the wheel, as shown in Fig. 2. This figure also shows one of a number of nozzles that direct jets of steam against the buckets of the wheel. The nozzle is controlled by a valve, as shown, and from the valve seat to the discharge its internal diameter increases progressively, allowing the steam to expand, so that when it impinges upon the wheel it is at comparatively low pressure but very high velocity. At the opposite side of the wheel a number of exhaust openings convey the steam to the atmosphere (or, preferably, to a condenser, since it is perfectly practicable to operate these machines with a vacuum as high as 27 ins. or more). The construction of the wheel, as shown in Fig 1, is the outcome of many attempts to devise a wheel that would be perfectly safe at the high peripheral velocities—up to 1,300 ft. per second—that are used here. The center section, of wheel proper, is of nickel steel, turned and balanced with great care. Buckets drop-forged from steel are driven into slots milled in the rim of the wheel, and join closely on the outside so as to make closed passages instead of troughs. This prevents all loss of power through centrifugal effect. The web of the wheel just inside the rim is turned down quite thin, so that if excessive speed occurs the wheel will break here instead of in the heavy masses of the interior of the wheel. Several wheels have been intentionally run up to this breaking point without further damage to casing or surroundings.

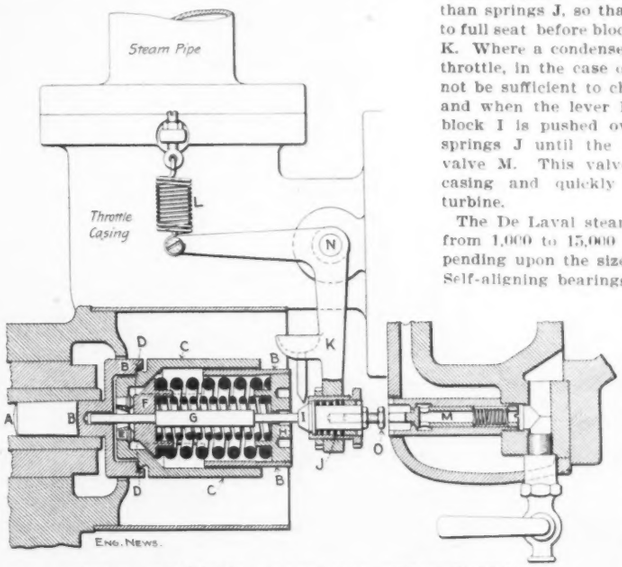


FIG. 3. GOVERNOR OF DE LAVAL STEAM TURBINE.

The high speeds at which these wheels are run also require that the destructive vibration that would occur with even slight non-coincidence of structural and gravity axes be avoided. This is done by allowing the shaft to spring sufficiently to let the wheel rotate about its gravity axis. Small wheels are fitted as at A in Fig. 1. A taper sleeve is shrunk on the shaft, and the wheel is forced over this sleeve. As will be seen, the shaft has bearing only in part of the length of the sleeve. Larger wheels are made solid for strength, the shaft being screwed to the wheel, as shown at B, Fig. 1.

Regulation of the wheel is to a certain extent reached automatically by the relation between the velocities of steam and wheel. This regulation is not close enough, however, for general use, and also does not provide against the effect of increased steam pressure. Fig. 3 shows the governor used to accomplish close and quick regulation. Speed curves obtained with it show greater steadiness for sudden maximum variations in load than the best types of compound engines. A is a gear shaft driven by the turbine; B is the governor body fitted by a taper shank into the end of the shaft; C, C are weights pivoting on knife edges D, and pressing, by means of hardened pins E, against the follower F. The latter is held in place by springs acting against the adjusting nut H, screwed into the outer end of the governor body. Follower F actuates pin G, which in turn moves the throttle lever K by means of block I, held by springs J. The throttle lever K is held in place by springs L, but these are weaker than springs J, so that the throttle will be moved to full seat before block I moves in its case in lever K. Where a condenser is used, the closing of the throttle, in the case of sudden drop of load, may not be sufficient to check the speed of the wheel, and when the lever K can move no farther the block I is pushed over against the pressure of springs J until the adjustable screw O strikes valve M. This valve admits air to the wheel-casing and quickly checks the speed of the turbine.

The De Laval steam turbines run at speeds of from 1,000 to 15,000 or even 20,000 r. p. m., depending upon the size and capacity of the wheel. Self-aligning bearings of the best type are used, and the friction losses, being entirely in the bearings, are very low. The losses, moreover, remain nearly constant at all loads, and the efficiency shows surprisingly small variation for a great range of loading. Fig. 4 shows curves of steam consumption per brake horse-power hour obtained from a compound condensing engine of the Corliss type and a De Laval steam turbine of approximately equal capacity. The comparison is seen to be strikingly in favor of the turbine.

The speeds at which the De Laval steam turbines normally run will in most cases preclude all attempts at direct utilization without gearing. Speed reduction is regularly accomplished in installations of these wheels by cut-steel gears, two sets being used. The teeth of the gears are skewed, the direction of skew being opposite for the two sets; this arrangement gives very quiet running, yet obviates all end thrust on the shaft. Gears of this kind have shown little appreciable wear after continuous operation for a number of years.

The De Laval steam turbine has been applied successfully to a number of different purposes. Turbine motors, direct-connected dynamos, pumps for all services, head-lighting and train-lighting equipments, etc., have been manufactured and new combinations are being evolved from time to time. Fig. 5 shows a steam turbine direct connected to a duplex direct-current dynamo of 300 HP. The turbine is at the extreme right, the dynamo at the left, the gear case being between them. Centrifugal pumps are especially adapted to be used with steam turbines, and a number of types have been developed by this company for the purpose. A two-stage pump is an interesting novelty, pressures up to 200 lbs. per sq. in. being economically attained.

The manufacture and sale of these turbines and all related appliances in America is in the hands of the De Laval Steam Turbine Co., 74 Cortlandt St., New York., who have kindly furnished the data for the above description.

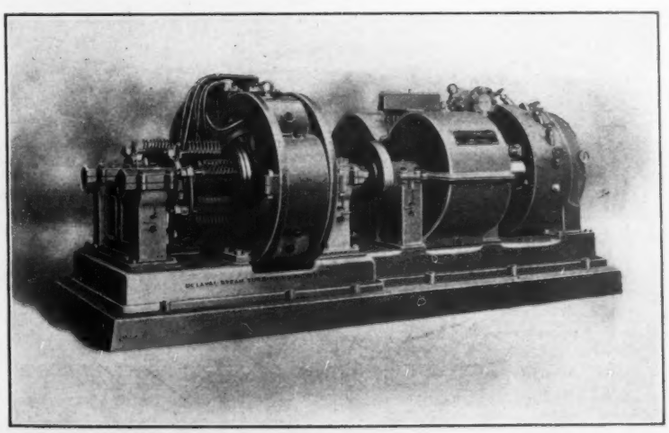


FIG. 5. VIEW OF THE DE LAVAL STEAM TURBINE DYNAMO.

THE ROTARY KILN PROCESS OF CEMENT MANUFACTURE.*

By William Harry Stanger,† M. Inst. C. E., and Bertram Blount,† Assoc. Inst. C. E.

The subject of this paper is a method of manufacturing cement that has come into use within the last few years in this country, on the Continent and in the United States, which presents such important advantages over older methods, that, in the authors' opinion, the complete re-

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†2 Broadway, Westminster, S. W., London.

placement of these by the new process may be regarded as certain. If this anticipation is realized, the new process will involve a revolution in a great industry, changing it from a somewhat primitive and empirical series of operations to one which depends upon the application of sound mechanical principles; will allow of a large economy in labor and in cost of fuel; and lastly, will ensure the production of a Portland cement better and more regular in quality than that at present manufactured. In order to give a clear account of the nature and advantages of the new process it is necessary to deal briefly with the chief features of older methods.

MANUFACTURE WITH FIXED KILNS.

Portland cement is made by heating to a clinkering temperature an intimate mixture of calcareous and argillaceous materials. The raw materials may be chalk, clay, limestone, shale or marl, but whatever their nature the two conditions of intimate mixture and exposure to a temperature at which the product is at least plastic are essential. In whatever manner and from whatever substances Portland cement is prepared, the ratio of the basic and acid oxides composing it approximates to that expressed by the equation,

$$\frac{Ca\ O}{Si\ O_2 + Al_2\ O_3} = 3,$$

all quantities being reckoned in equivalents, not in percentages. In practice, the ratio is kept appreciably below 3; that is to say, the amount of lime in the cement is lower than that required to saturate the whole of the silica and alumina by forming tricalcium silicate and tricalcium aluminate therewith. Under present conditions of manufacture this limitation of the lime is necessary for safety because, on account of imperfect and irregular burning, complete union of the acid and basic constituents of the cement cannot be insured. With a more nearly perfect process of burning the theoretical limits of composition can be closely approached, and a cement not merely stronger but very much safer can be manufactured. When chalk and clay are employed as the raw materials they are usually mixed in a wash-mill with sufficient water to form a slurry which can be pumped. The water necessary for aiding mixture and allowing transport by pumping has to be removed before the slurry can be burned. In this country drying is generally effected on floors heated by the waste gases of the kilns, which are commonly those known as chamber kilns. Fig. 1 represents a chamber kiln with its drying floor.

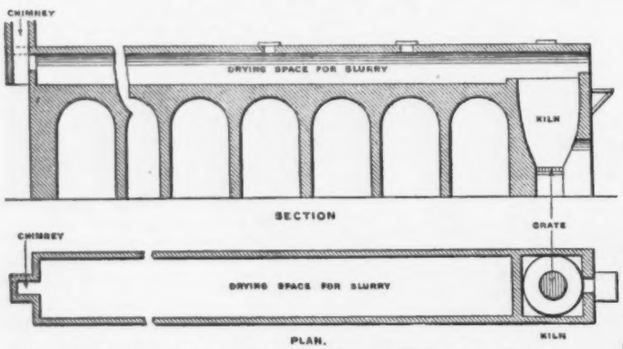


FIG. 1. CHAMBER KILN FOR BURNING PORTLAND CEMENT.

The kiln is a brickwork structure about 16 ft. in diameter and 18 ft. in height, having a grate at the bottom and opening into a long wide horizontal flue in which is run the slurry to be dried by the waste gases. The fuel used is coke, which is loaded into the kiln interspersed with the dried slurry; the quantity required is 40% to 50% reckoned on the weight of clinker produced. Coke is not only a relatively costly fuel, but is one liable to sudden and artificial fluctuations of price, a tendency highly inconvenient to the cement maker. The labor needed for loading and drawing the kilns is very heavy, and the clinker produced is far from uniform, often containing much under-burnt material which needs to be picked out before the clinker is ground. A kiln of this class of average size will need 5 days to 6 days for a complete trip, and will not produce more than about 35 tons of clinker per week.

When dry raw materials, e. g., shale and limestone, are used, some form of continuous kiln is generally employed. The materials are finely ground, intimately mixed and damped sufficiently to enable them to be molded into rough bricks. These are burnt in ring or shaft kilns. The ring kiln of the Hoffmann type is largely used in this country in the manufacture of bricks, but is rarely employed for cement. It is economical of fuel, needing only about 15% to 20% on the weight of the clinker produced, but requires a large amount of fairly skilled labor in stacking the bricks of cement material into the chambers of the kiln, and in regulating the firing by feeding fuel into the spaces left between the stacked bricks; it has also to be unloaded by hand. The necessity of regular stacking of the material to be burnt makes the Hoffmann kiln less suitable for treating material such as cement, which becomes deformed when hot, than for burning building bricks and the like which retain the regularity of their shape.

The Dietsch kiln is a typical shaft kiln and is largely and successfully used for burning cement. As shown in Fig. 2, it is a continuous kiln, having a feeding door at the base of the stack, a burning chamber and a cooling chamber through which the material to be burned successively passes. It is economical of fuel, using 15% to 20% of the weight of the clinker produced, but is costly in labor.

Both the Hoffmann and the Dietsch kilns can be used for wet raw materials, but they require supplementary drying arrangements by which the slurry may be dried sufficiently to allow of its being molded into bricks. The amount of fuel necessary for drying is usually somewhat greater than that needed for burning, so that the total amount of fuel required, viz., 35% to 40% on the clinker, is not much smaller than that needed for chamber kilns, but a cheaper kind of fuel can be used, namely, small coal.

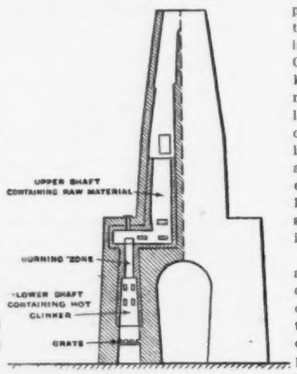


Fig. 2. Dietsch Continuous Kiln for Burning Portland Cement.

The principle of continuous working is so attractive, on account of its economy in fuel and its increase of output per kiln, that it has been embodied in various other forms of kiln. These are in general vertical cylindrical shafts not unlike a running lime kiln, but usually with a flue or chimney at the upper end and loading doors at the base of this flue. The clinker is drawn at the bottom where there is usually some kind of removable grate. In one kiln of this class a blast of air is blown in at the base of the kiln. The charge is regulated so that the mixture of coke and cement material is in full ignition at a point about one-third of the way down the kiln, its products serving to heat the raw material in the upper part, and the hot clinker in the lower part yielding its heat to the incoming air. Kilns of this class are economical of fuel, but as a rule require the use of coke instead of small coal, and need a good deal of skill in loading. The hot plastic clinker is liable to stick to the walls of the kiln, causing the charge to hang; this not only hinders the proper working of the kiln, but also acts on the lining and hastens its destruction. Unless skilfully worked these kilns are apt to yield a good deal of underburnt clinker which has to be picked out.

The quantity of clinker produced by these different classes of fixed kiln varies considerably with local circumstances, but may be stated in round figures as follows: Chamber kiln, 35 tons per week; Dietsch kiln, 70 tons per week; Schneider kiln,* 70 tons per week; Hoffmann kiln 28 tons per week for each chamber.† With all these varieties of fixed kiln the amount of labor needed for handling the raw material and clinker is large, whether the kiln be continuous or discontinuous. Moreover, kilns of the continuous class when wet raw materials are used require an elaborate drying plant to prepare the raw material before it is fed into the kiln to be burnt. In whatever class of fixed kiln it is produced the clinker is irregular in quality, containing a good deal of imperfectly burnt material; unless this is picked out most carefully sufficient underburnt material remains to impair the quality of the finished cement in a serious degress. Finally the finished cement needs to be matured by storage before it can be used with safety for important work.

*This is a kiln of the continuous cylindrical shaft type last mentioned.

†A ring kiln of 14 chambers each, having a capacity of 40 tons, will give 560 tons of clinker for a complete round trip, which will take about 10 days. This represents an output of 56 tons per day, or 392 tons per week for the whole kiln, i. e., 28 tons per week for each chamber.

MANUFACTURE IN ROTARY KILNS.

A rotary kiln for the manufacture of cement consists in its simplest form of a long cylinder of boiler plate lined with refractory material, inclined slightly to the horizontal, and capable of being rotated by suitable gearing. There is a powerful burner or other suitable source of heat at the lower end, and at the upper end is a conveyor or equivalent device by which the raw material may be fed in. The material is caused to travel down the cylinder by the joint effect of the rotation and the inclination of the kiln, and is systematically heated as it proceeds until at the lower end it reaches a clinkering temperature and falls from the end of the kiln as finished clinker. In 1877 Thomas Russell Crampton, M. Inst. C. E., patented a process for burning cement in rotary kilns, but appears not to have put his invention on a manufacturing footing. It may be accepted that the earliest form of rotary kiln which approached practical success was invented in this country by the late Mr. Frederick Ransome, Assoc. Inst. C. E.; this kiln may be regarded as the forerunner of modern rotary kilns now being erected or at work in England or abroad. Ransome's English patent is dated May 2, 1885, and, in view of the subsequent development of the rotary process, affords an interesting object of study.

RANSOME KILN.—The Ransome kiln, Fig. 3, consists of a cylindrical furnace A, set at a slight inclination, carried on rollers, and rotated by worm gearing B. At the upper end powdered raw material is fed in by the hopper C, and travels down the furnace, meeting burning producer gas entering by the pipe D. The burnt material falls into the pit E, and any raw material which may be blown back up the furnace is caught in the settling pit F, whence it can be returned to the hopper.

The inventor states that whereas in ordinary methods of burning cement it has always been necessary "to grind the cement after burning to bring it to the requisite degree of fineness," in his process "by introducing the cement material into the rotating chamber as a fine powder the necessity for grinding the cement after burning is entirely obviated." This idea, which is put forward in his provisional specification, is emphasized in the complete specification, where the following passage occurs: "The slurry is dried, then pulverized, and afterwards sifted to bring it to the degree of fineness required in the sifted cement," also one of the claims of the patent is for a process of manufacturing cement by burning dry powdered raw materials, "so that the cement produced may be used without subsequent grinding."

It is abundantly evident that one of the chief objects which Mr. Ransome had in view was the abolition of the costly process of grinding clinker. His claim to accomplish this was made in ignorance of the fact that at the temperature necessary for burning Portland cement the material becomes plastic and sticky, and although it may be in the finest powder before burning, yet it will cohere and form small nodules or lumps when burnt. He also failed to see that systematic heating of the raw material by passing it through the kiln in a direction opposite to that of the burning gases was of fundamental importance, because he suggests introducing the raw material at the end where the burner is situated as an alternative to the correct and rational method of feeding it in at the end remote from the burner. But although in error in these two important respects, the inventor saw clearly that a great saving in the cost of production (largely due to economy in labor) would be effected by a rotary process, and that the cement made by such a process would be more uniformly burnt than that made in masses in a fixed kiln.

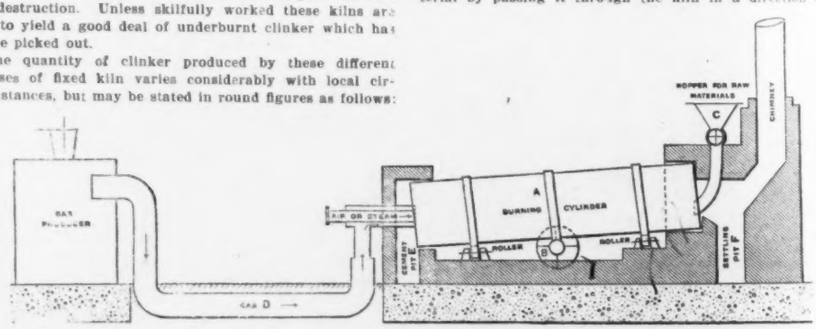


FIG. 3. ORIGINAL RANSOME ROTARY KILN FOR BURNING PORTLAND CEMENT.

In spite if its merits in principle, the Ransome process was a complete failure in practice. One of the chief difficulties encountered was the behavior of the cement clinker in contact with the lining of the kiln. At the

hottest part of the cylinder where a clinkering temperature was obtained, it was found that the clinker, as it formed, adhered to the firebrick lining and formed a ring, obstructing the passage of further supplies of raw material. It is not too much to say that the success of the modern rotary process depends largely on the methods which have been adopted for obviating this difficulty; these will be dealt with in a later part of the paper.

There were other troubles in the Ransome process. The finely-divided raw material was carried by the draft out at the upper end of the kiln and had to be caught and returned. The use of producer gas without a regenerator scarcely allowed regular attainment of a temperature high enough to burn the clinker completely. When a regenerator was used it speedily became choked with the dust carried away by the draft. The cement obtained was inconveniently quick-setting, for a reason which will be discussed in due course. The burning cylinder was only about 25 ft. long, and this length was insufficient to allow of the economical use of the fuel, and, moreover, led to the burning out of the tube used to feed in the raw materials at the upper end of the cylinder.

QUANTITY OF HEAT REQUIRED TO BURN CEMENT.—A substantial improvement on the Ransome apparatus was made by Mr. Wilfrid Stokes, who realized clearly that one of the merits of a properly contrived rotary process is the economical and systematic use of heat. The waste gases departing from a burning cylinder, such as Ransome's, contain a large amount of heat, as does the white-hot clinker falling from the lower end of the burning cylinder. The heat from both sources is effectively utilized in the Stokes process. In order to determine what are the limits of possible economy the quantity of heat needed to burn a given weight of cement may be calculated, the results being applicable not only to the Stokes apparatus, but to the rotary process generally. For the production of 1 ton of clinker an average quantity of 1½ tons of dry raw material is needed. This will contain about 1¼ tons of chalk or limestone and ¾ ton of dried clay or shale. When this mixture is heated, energy is expended chiefly in decomposing calcium carbonate. The energy needed for the decomposition of 1,125 kilograms (about 1¼ tons) of calcium carbonate is 478,012 calories. The dehydration of the aluminum silicate in the clay requires the expenditure of a small quantity of energy, but the amount is not accurately known. The reaction of the lime liberated by the decomposition of the calcium carbonate on the silica and alumina of the clay to form calcium silicates and aluminates is probably exothermic, and this supplies a small amount of heat. These plus and minus quantities may be regarded without serious error as balancing each other. It comes about, therefore, that the heat needed to convert 1½ tons of dry raw material into 1 ton of clinker is in round figures 480,000 calories; 60 kilograms of coal having a calorific value of 8,000 calories will furnish this amount of heat, corresponding with a consumption of coal of 6% on the weight of clinker produced. How nearly this limit may be approached in practice may be usefully considered.

In any properly contrived continuous process for burning cement the incoming air is used to cool the finished clinker, and the outgoing furnace gases are used to heat the raw materials. The temperature of the outgoing clinker may be taken at 100° C. (212° F.) and that of the waste gases at 300° C. (572° F.). The heat contained in the outgoing clinker and that in the waste gases are the only losses of energy (other than radiation) from the apparatus. These, together with the energy required to bring about the chemical changes involved in the production of clinker from its raw materials, are a measure of the total amount of heat which must necessarily be expended in producing a given weight of clinker. But if this heat is obtained by the combustion of coal, the air necessary for combustion will constitute the greater part of the waste gases, and the calories carried away by the waste gases will depend on the weight of coal burned, which, in its turn, must suffice to supply these calories. Supposing the coal to contain an average of 80% of carbon and 5% of hydrogen, the amount of air necessary to burn 1 kilogram will be approximately 11 kilograms. Allowing the usual surplus of 100%, the total weight of air will be 22 kilograms, and, neglecting the ash of the coal, the total weight of the gaseous products of combustion will be 23 kilograms. Calling x the number of kilograms of coal needed for burning 1,000 kilograms (1 ton) of clinker, it is evident that the number of kilograms of waste gases will be 23 x. The whole of this has to be heated from 15° C. (60° F.) to 300° C. (572° F.).

Similarly the CO_2 liberated by the decomposition of the calcium carbonate of the raw materials has to be heated through the same range of temperature. Thus the causes of expenditure of heat which have to be met to produce 1,000 kilograms of clinker are:

	Calories.
(1) For decomposition of 1,125 kilograms $CaCO_3$	478,012
(2) For lost heat in clinker (specific heat 0.2 temperature 85° C. above that of the air)	17,000
(3) For lost heat in waste gases: (a) 495 kilograms of CO_2 from $CaCO_3$.. (b) 23 x kilograms of products of combustion from coal and air (average specific heat 0.24, temperature 285° C. above that of the air).....	(23 x + 495) × 0.24 × 285

The whole of this heat has to be provided by x kilograms of coal having a calorific value of 8,000 calories. Hence

8,000 x = 17,000 (heat in clinker) + 478,012 (heat needed to decompose $CaCO_3$) + (23 x + 495) × 0.24 × 285 (heat in waste gases).

$$\therefore x = 82.3 \text{ kilograms,}$$

i. e., 8.23% on the weight of the clinker produced.

This figure, if increased by an allowance of 20% for radiation, gives 9.88% as the minimum consumption possible under the conditions set forth above. The best results hitherto attained in practice have required more than double this amount. When wet raw materials are used, the evaporation of their water requires a further consumption of fuel. This may be calculated with a fair degree of accuracy. Slurry, in the condition in which it is pumped, usually contains about 40% of water. For every 1½ tons of dried slurry (corresponding with 1 ton of clinker) there would be 1 ton of water (say, 1,000 kilograms). The heating of this quantity of water from 15° C. to 100° C. and its evaporation from 100° C. requires 1,000 × 85 + 1,000 × 537 calories = 622,000 calories. Assuming the temperature of the waste gases to be, as before, 300° C., there must be added to this water vapor a further quantity of 1,000 × 200 × 0.48 calories = 96,000 calories. The total increment to be met is therefore 718,000 calories. It follows that when wet slurry (containing 40% of water) is used as the raw material, the total amount of heat needed for the production of 1 ton (1,000 kilograms) of clinker will be:

	Calories.
(1) For decomposition of 1,125 kilograms $CaCO_3$	478,012
(2) For lost heat in clinker (specific heat 0.2, temperature 85° C. above that of the air)	17,000
(3) For lost heat in waste gases: (a) 495 kilograms of CO_2 from $CaCO_3$ (specific heat 0.24, temperature 285° C. above that of the air)	33,858
(b) 1,000 kilograms of H_2O from 15° C. to 300° C.	718,000
(c) 23 x kilograms of products of combustion from coal and air (average specific heat 0.24, temperature 285° C. above that of the air)	23 x × 0.24 × 285

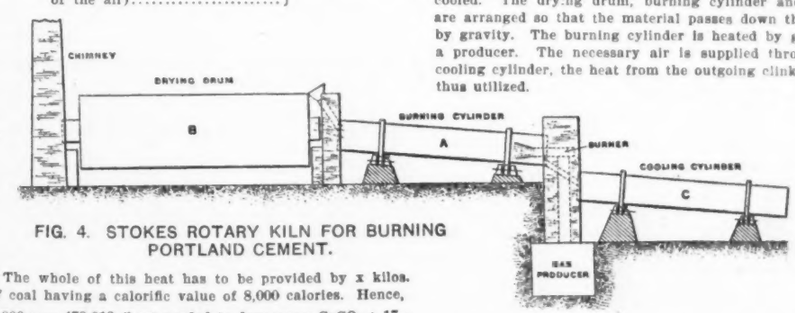


FIG. 4. STOKES ROTARY KILN FOR BURNING PORTLAND CEMENT.

The whole of this heat has to be provided by x kilos. of coal having a calorific value of 8,000 calories. Hence,

8,000 x = 478,012 (heat needed to decompose $CaCO_3$ + 17,000 (heat in clinker) + 718,000 (heat in steam) + 33,858 (heat in CO_2 from $CaCO_3$) + 23 x × 0.24 × 285 (heat in products of combination).

$$\therefore x = 194.0 = 19.40\% \text{ on the weight of the clinker.}$$

Allowing, as before, 20% of this calculated value to cover loss by radiation, there results 23.28% of coal reckoned on the weight of the clinker as necessary for burning raw materials containing 40% of water.

A sensible economy is secured if the waste gases escape at an appreciably lower temperature, e. g., 200° C. Under these conditions the calculated minimum quantity of fuel is 17.01% on the weight of the clinker produced. The distribution of heat expenditure may be usefully stated in tabular form; loss by radiation is in this case omitted.

Dry raw materials:	Per cent.
Heat necessary for decomposition of calcium carbonate	72.6
Heat lost in clinker	2.6
Heat lost in waste gases	24.8
	100.0

Wet raw materials: (Slurry containing 40% of water.)

	Temperature of waste gases 300° C. Per cent.	Temperature of waste gases 200° C. Per cent
Heat necessary for decomposition of calcium carbonate	30.8	35.1
Heat lost in clinker	1.1	1.2
Heat necessary to evaporate water and to heat water vapor to temperature of products of combustion	46.3	49.3
Heat lost in products of combustion, including CO_2 from $CaCO_3$	21.8	14.4
	100.0	100.0

A glance at these figures will show the enormous advantage in fuel consumption possessed by the user of dry raw materials. This advantage is so considerable that it would appear rational to avoid any addition of water to existing raw materials. But in English practice this addition is deliberately made: moist chalk and clay are washed to a slurry containing as much as 40% to 50% of water, all of which has to be dried off before the material can be burned. The cause of this procedure is to be found partly in the belief that complete admixture cannot be obtained without the use of water, and partly in the imperfections of most of the older types of drying apparatus. The presence of flints in the chalk is also a good reason for washing. The full discussion of this question is outside the limits of this paper, and it is sufficient for the present purpose to draw attention to what is on the face of it an anomalous state of things.

STOKES KILN.—In the Stokes process precautions were taken to effect a considerable economy in fuel. The whole apparatus was particularly well thought out, and its failure to realize the expectations of its inventor is greatly to be regretted, the more so as it delayed for nearly ten years a much-needed improvement in an important industry, and allowed the center of interest to shift from this country, which is the birthplace of the rotary process, to the United States, which is its country by adoption and where it has developed and prospered. The plant is shown in Fig. 4. A is the burning cylinder, about 35 ft. long and 5 ft. in diameter, constructed of steel plates and mounted on two sets of live rollers resting on a cast-iron cradle, with freedom to allow for expansion and contraction. The cylinder is driven by a small engine and spur gearing; it is lined with refractory bricks. The waste gases from the burning cylinder pass through the drying drum B, about 40 ft. long and 12 ft. in diameter. At each end of the drum is a roller path resting on supporting wheels, and the drum is slowly rotated by worm gearing driven by a small engine. The slurry is fed onto the outside of the drum by means if a dipping arrangement which delivers a definite quantity of slurry from a long trough (not shown in the figure) above the drum. The slurry adheres to the drum and is dried by the time the drum has nearly completed a revolution, when it is scraped off by a series of chain scrapers driven along the top of the drum and delivered into the feed-shoot of the burning clinker. The clinker emerging from the lower end of the burning cylinder falls into the cooling cylinder C, 35 ft. long and 5 ft. in diameter. This cooling cylinder is of steel, unlined but provided with gills which aid in abstracting heat from the clinker to be cooled. The drying drum, burning cylinder and cooler are arranged so that the material passes down the series by gravity. The burning cylinder is heated by gas from a producer. The necessary air is supplied through the cooling cylinder, the heat from the outgoing clinker being thus utilized.

The above description has been supplied to the authors by Mr. Wilfrid Stokes, for whom they made certain investigations when the apparatus was being designed. Numerous difficulties, chemical and mechanical, had to be dealt with in the course of this work. It is not too much to say that Mr. Stokes's ingenuity and resource enabled him to overcome almost all these, but certain obstacles appeared practically insuperable. It was necessary in the first place to establish at what rate drying could be effected with the waste gases in the form of dryer selected. Next it had to be recognized that the mixture of chalk and clay proper for the manufacture of cement by the old process was not suitable for the new method. This is because the ash in solid fuel (e. g., coke) consists chiefly of silica and alumina, and may be properly regarded as acting like the clay; therefore, there must be enough calcium carbonate in the slurry to unite with these bodies if a normal cement of proper composition is to be produced. If such a slurry be burned with a fuel which contains no ash, such as producer gas, the content of lime in the resulting cement will be unduly high. In the third place it was found that the cement, being almost free from sulphates (which are mainly derived from the coke or other solid fuel), was abnormally quick setting; the regulated addition of gypsum to lengthen the setting time was therefore necessary. But these were small matters compared with the difficulty of maintaining a sufficient and uniform temperature in the burning cylinder.

Finally, and this was the worst trouble to be met, the provision of a satisfactory lining for the burning cylinder appeared impossible of attainment. When ordinary firebricks were used they were speedily attacked by the clinker which corroded and destroyed them, and was itself spoiled. A basic lining naturally suggested itself, but magnesia bricks were dear and conducted heat over-readily. Bricks of bauxite were prepared, but were found to be weak and friable, thus failing from mechanical defects although fairly satisfactory chemically. The manner in which this lining difficulty has since been overcome by other inventors will be described in due course.

DEVELOPMENT OF ROTARY KILNS IN AMERICA.—The ideas underlying the Ransome process took root in the United States and bore fruit there. With characteristic energy and determination American inventors began to try to make cement with rotary kilns and to improve upon the unsuccessful attempts of their predecessors. In this task they were much aided by the fact that they could use petroleum—a fuel too dear to be employed here. The ease with which the temperature of the kiln could be controlled when a jet of burning petroleum was the source of heat allowed many somewhat crude attempts to reach a qualified success. But for a world-wide industry petroleum is not a practically attainable fuel; even in America it is not so generally available as coal, and moreover its price is artificial, and is controlled by a few hands. The abolition of the necessity to use petroleum has made the rotary process adaptable for all industrial countries.

HURRY & SEAMAN KILNS, ATLAS CEMENT CO.—In the autumn of 1898 one of the authors visited the United States to inspect and report upon a rotary process in use at the works of the Atlas Cement Co., at Northampton, Pa., and had the advantage of conferring with the joint inventors, Mr. E. H. Hurry and Mr. H. J. Seaman. The Atlas Cement Co.'s works form probably the largest cement manufactory in the world; and the whole of the plant is on the rotary system devised by these gentlemen. There are running at present 51 kilns with an average output of between 8,000 and 9,000 barrels per day (i. e., between 8,000 and 9,000 tons per week), a quantity four times the output of most works which are regarded as large on this side of the Atlantic. The size of the works is, of course, interesting merely as showing that the process is in no sense experimental, but is already at work on a huge scale. When it is stated that the Atlas Cement Co. is now erecting another plant of 48 kilns which will almost double its output, it may fairly be concluded that the process is economical and remunerative.

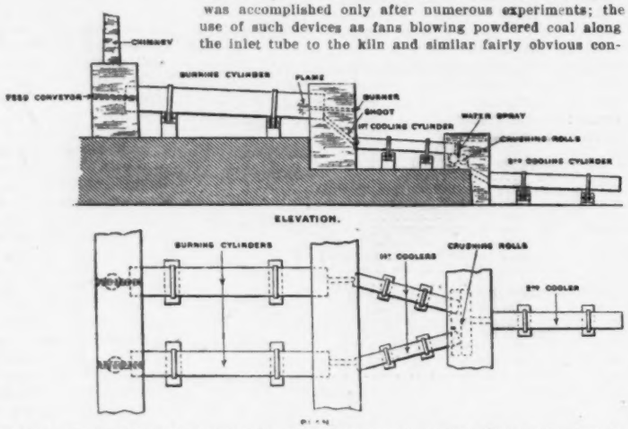


FIG. 5. THE HURRY & SEAMAN ROTARY KILN USED BY THE ATLAS CEMENT CO.

The raw materials used by the Atlas Cement Co. are a calcareous shale containing about 70% of calcium carbonate and a limestone containing about 93% of calcium carbonate, the two being mixed in such proportions as to produce a normal clinker. The shale and limestone are crushed in Gates crushers, passed through rotary sieves, dried in a rotary drier and ground in Huntingdon mills to a fineness of 10% on a 100 × 100-mesh sieve. The dry well-mixed powder is carried by conveyors to stock boxes above the feeding ends of the rotary kilns; the capacity of these boxes is sufficient to supply the kilns with raw material for 48 hours, thus allowing the puverizing plant to be shut down over Sunday while permitting the kilns to run on. This is necessary because the essence of the rotary process is its continuous working day and night throughout the year.

In the Hurry-Seaman plant, Fig. 5, the kilns are rotating cylinders 60 ft. in length and 6 ft. 6 ins. in diameter at the lower end and 5 ft. in diameter at the upper end, and inclined ⅞-in. per ft.; they are carried on rollers and rotated by suitable gearing at a rate varying according to the conditions of burning between nine and 32 revolutions per hour. At the lower end is a burner fed with powdered coal, shown diagrammatically in the figure, which is injected by means of a blast of air. The burning coal dust produces a blast flame of such power as to raise the lower part of the kiln to a clinkering temperature. From the lower end the temperature gradually diminishes to the upper end, from which the comparatively cool gases escape into a chimney. The raw materials entering at the upper end are gradually raised in temperature as they descend towards the lower or furnace end. The rate of descent is regulated by the angle of inclination of the cylinder and by its speed of rotation, and is so adjusted that when the raw materials reach the "clinkering zone," i. e., the length (about 10 ft.) at the lower end of a cylinder which is maintained at a clinkering temperature by the action of the blast of coal dust, the carbonate of lime has been decomposed, the clayey material dehydrated and interaction between the lime and the silica and alumina has begun. The completion of this interaction and the production of clinker then occur in the clinkering zone and fully burnt clinker passes out at the lower end of the cylinder.

FUEL.—Although this description will serve to give a general idea of the construction and operation of the kiln proper it does not include certain details which are of the highest practical importance and make all the difference between successful use of the rotary system and failure partial or complete. The method of heating the kiln is one of these details. The coal used at the Atlas Cement Works at the time of the authors' visit had the composition

	Per cent.
Volatile carbonaceous matter	30.42
Fixed carbonaceous matter	60.30
Ash	8.38
Moisture	0.90
	100.00

As bought, in the form of slack, it contained more moisture than is shown in the analysis, which is that of the fuel ready for use. The slack is dried in a rotary drier, ground in Huntingdon mills and conveyed to stock boxes arranged over the burner ends of the kilns. Although this coal is cheap and suitable, yet other kinds, even anthracitic coal, are equally applicable. When anthracite is used its hardness somewhat increases the work of grinding, but when finely powdered it makes an excellent fuel. The burner itself is essentially an air injector carrying in the fine dry coal dust which has been previously pushed by a screw conveyor into the region of the pull of the injector, and is kept well agitated, so that it may the more easily distribute itself when mixed with the injected air and that which is pulled in.* The invention of an efficient burner was accomplished only after numerous experiments; the use of such devices as fans blowing powdered coal along the inlet tube to the kiln and similar fairly obvious contrivances does not produce the uniform and easily controlled flame which is essential to the satisfactory burning of cement clinker.

LINING.—The lining of the kiln is another matter which needs special mention. In order to explain the cause of the difficulties encountered when ordinary firebrick lining is used, and to indicate the nature of the remedy which has been found, a short excursion into the chemistry of refractory materials is requisite. The ordinary material used for lining furnaces is firebrick, which is substantially composed of silica and alumina; it contains, as minor constituents, oxide of iron, magnesia, and alkalies. The percentages of the chief constituents may range from 75% of silica and 20% of alumina, to 55% of silica and 40% of alumina. Such bricks behave as an acid substance towards Portland cement clinker, which, being rich in lime, is a basic material. The acid brick and the basic clinker flux together and unite to form a fusible mass similar to blast-furnace slag. This action is inevitable at a clinkering temperature, and, if allowed to proceed, gradually causes the destruction of the firebrick lining and the deterioration of the cement clinker which is contaminated by the slag-like product of its action on the firebrick. Many attempts have been made to remove these inconveniences. As alumina acts as a weaker acid than silica, bricks relatively rich in alumina have been employed. The following analysis gives the composition of a brick of this class:

	Per cent.
Silica ($Si O_2$)	55.82
Alumina ($Al_2 O_3$)	37.98
Ferric oxide (Fe_2O_3)	4.02
Lime (Ca O)	Nil
Magnesia (MgO)	0.78
Soda (Na_2O)	0.88
Potash (K_2O)	0.37
	99.85

But this brick is still strongly acid and is severely attacked in practice. In order to prevent the clinker attacking the lining the latter must be basic. No better form of basic lining can be conceived than one composed of cement clinker itself; obviously it must be without action on cement materials clinkered in contact with it. But it is not a convenient material of which to make bricks with which the lining may be constructed per se. A process by which a protective coating of clinker can be applied to an existing lining of firebrick would meet the requirements of the case exactly. This process has been worked out by Messrs. Hurry and Seaman. It is executed in the following manner:

A coating of common salt is applied to that part of the firebrick lining of the kiln which is exposed to a clinkering temperature. The kiln is then heated and the raw cement material is introduced into the kiln and raised to a clinkering temperature. At this temperature it is plastic, and adheres to the heated surface, on to which it is beaten or pressed down to form an adherent protective coating. The junction between the firebrick and the coating of clinker is protected from the full clinkering temperature by the thickness of the clinker coating, and corrosion of the firebrick by the clinker is prevented. The use of salt to form a sticky surface to which the clinker adheres in the first instance, though advantageous, is not necessary; if the use of salt be dispensed with, the bare firebrick lining is heated to a high temperature, and to it is applied an adherent coating of clinker, which serves as an effectual protection of the junction of the two materials from further fluxing.

This simple and beautiful device has changed the entire aspect of cement manufacture in rotary kilns. It has abolished the whole of the difficulties which have arisen from the destruction of the lining, and has made possible the use of ordinary firebricks, which are cheap and good non-conductors of heat in place of expensive magnesia bricks which conduct heat too freely and are moreover liable to crack. By the use of the air injector coal-dust burner, and by the provision of a basic coating for the hottest part of the kiln, a uniform and high temperature can be maintained which produces clinker of excellent quality.

At the time of the authors' visit to the Atlas works samples were drawn direct from the mouth of the kiln and found to be of a quality hardly approached by the best clinker made in any fixed kiln; moreover, the quality was uniform. The important advantage accrues that the clinker requires no picking, and one large source of difficulty and expense occurring in the older process disappears.

The further course of the clinker as it leaves the burning cylinder is as follows: The clinker drops from the burning cylinder into a second rotating cylinder, see Fig 5, about 30 ft. long and 3 ft. in diameter, revolving about six times as fast as the burning cylinder. This is lined with firebrick, and through it passes a current of air which goes to feed the flame of burning coal dust. The greater part of the sensible heat in the clinker is thus saved and utilized. The clinker, still moderately hot, falls on to three crushing rolls contained in a housing and moistened by a spray of water. As shown in the figure a pair of kilns with their accompanying first cooling cylinders converge so as to deliver the clinker on to these rolls and from this point a single secondary cooling apparatus serves this pair of kilns. The object of the rolls is to crush large lumps of clinker which may have been formed by the aggregation of a number of small fragments adhering together when plastic in the burning cylinder. These lumps being built up of small pieces loosely stuck together differ entirely from the tough hard masses formed in a fixed kiln fed with blocks or bricks of raw material, and are readily broken up to the size of a hazel nut. The warm moist clinker passes down a third rotating cylinder 60 ft. long by 5 ft. in diameter, lined with hard cast-iron plates provided with shelves so as to toss and tumble the pieces as they creep down. Air is drawn in through this cylinder by means of a chimney which also carries off the water vapor from the housing of the rolls. It is intended that the clinker shall emerge from the end of the last cooling cylinder, in a slightly moist condition, and to ensure this, regulation of the water at the rolls is supplemented by a small jet at the end of the last cooler.

The finished clinker falls into trucks, each having a capacity of 10 tons, which are moved by a traverser and elevator to the pulverizer building, where the material is tipped into iron stock boxes above the pulverizers. The clinker is then slightly warm to the hand and moist, but not wet. The water lodges in the small interstices of the clinker and serves a purpose to be explained later. It might be supposed at first glance that cement clinker would be injuriously affected by this wetting, but a little consideration will show the reverse to be true. It is well known that cement aerated by storage and turning over is improved not merely in soundness, but in strength. This improvement is due to the hydration of those unsaturated lime compounds whose presence is a standing source of instability and weakness. However perfectly the raw materials may be mixed and burned, a certain amount of these unsaturated lime compounds is present. By the process here described these are automatically and systematically provided with a sufficiency of water (readily controllable) for their saturation. The peculiar nature of the clinker, with its numerous interstices, favors the lodgment of this small quantity of water without rendering the clinker wet as a whole. When this clinker is ground no clogging of the mills takes place, and the small amount of water is distributed evenly throughout the finished cement and slakes any unsaturated lime compounds. In this way the same object (viz.: maturing) is effected rapidly, cheaply and perfectly, which is slowly and expensively brought about by the old cumbrous method of turning over and exposing the finished cement. The quality of the cement may be judged from the results of the authors' tests and analyses given below:

Fineness: 15¼% on 120 × 120 sieve; 3¾% on 76 × 76 sieve; ½% on 50 × 50 sieve; few nibs on 25 × 25 sieve.

Setting Time—Over seven hours.

*The powdered fuel burner used at the Alpha Portland Cement Works was illustrated in Engineering News of June 20, 1901.

Tensile strength (1 in. × 1 in. section):

Neat cement		3 sand, 1 cement	
7 days.	28 days.	7 days.	28 days.
Lbs.	Lbs.	Lbs.	Lbs.
640	820	260	370
640	820	240	370
620	810	230	370
610	800	220	360
600	780	210	360
590	770	210	360
Average. 613½	800	228½	360

Color good. Faija pat, tested in moist air and warm water for 24 hours, satisfactory.

Deval tests (1 in. × 1 in. section):

3 sand, 1 cement, by weight.			
2 days, hot. lbs.	7 days, cold, lbs.	7 days, hot, lbs.	28 days, cold, lbs.
310	300	340	390
260	280	325	380
215	270	300	370
Average. 261⅔	283⅓	321⅔	380

BAUSCINGER TESTS.—By this means the alterations in length of a test bar of cement, 100 mm. long, are determined with an accuracy of 1/200 mm. The results are stated in units of 1/100 mm.

	Wet bar.	Dry bar.
1 day	+ 1.5	— 7.0
7 days	+ 3.5	— 9.5
28 days	+ 4.5	— 13.5

+ indicates expansion. — indicates contraction.

These alterations are such as occur with Portland cement of good quality, which expands slightly when kept in water and contracts slightly when kept in air.

	Per cent.
Analysis.—Silica (SiO_2)	20.36
Insoluble residue (sand and clay)	0.44
Alumina (Al_2O_3)	7.26
Ferric oxide (Fe_2O_3)	3.24
Lime (CaO)	61.90
Magnesia (MgO)	3.10
Sulphuric anhydride (SO_3)	1.36
Carbonic anhydride (CO_2)	0.33
Water (H_2O)	1.97
Soda (Na_2O) and Potash (K_2O) and loss	0.04
	100.00

The composition of the sample is normal for Portland cement of good quality.

To complete this sketch of the Hurry-Seaman system, it may be said that the stock boxes for the clinker have a capacity for 48 hours' output, allowing the grinding plant to be stopped over Sunday, and from these it passes to mills, from which it is conveyed mechanically to store-bins. It is ground so as to leave between 8% and 10% of residue on a 100 × 100-mesh sieve. Before it is sent out it is mixed by screw mixers with a small quantity of plaster of Paris to lengthen its setting time, and is packed with as little hand labor as possible. Thus from the tipping wagons coming from the quarry to the final bags or barrels the material is untouched by hand, and passes automatically and continuously through all the stages needed to convert the rough limestone and shale into finely ground, sound and well-matured Portland cement.

It is convenient to take one of the plants in use at the Atlas Works as a unit, in order to describe the apparatus needed for a given output on the rotary system, viz.: 2,800 tons per week. A battery of 14 kilns, contained in a single building, may serve as this unit. The 14 kilns have 14 burners and preliminary coolers, 7 crushing rolls and 7 final coolers. There are four Gates crushers and one revolving dryer for the raw materials and nine Huntingdon mills for reducing the raw materials to fine powder. The coal requires one revolving dryer and four Huntingdon mills. The clinker is ground in 30 Huntingdon mills. The grinding apparatus is driven by an engine of 2,500 HP., and the kilns, coolers and subsidiary apparatus are driven by an engine of 300 HP.; a duplicate of this engine serves as a standby to ensure continuous working of the kilns and coolers. This provision of power and of grinding apparatus is probably larger than is absolutely necessary, and the whole plant is of very heavy and substantial build. A smaller margin might be used, and it is possible that this is the case with that portion of the works finished since the authors' visit, but it may be taken as approximately accurate that the entire plant of this one works is nearly four times the size given above. The magnitude of the undertaking may be understood from these figures. Its economy may be gathered from the following data relating to cost of materials, fuel and labor.

The cost of the process falls under the following heads:

COST OF PRODUCTION OF 1 TON (2,240 LBS.) OF PORTLAND CEMENT.

	Cost per ton of cement. s.	d.
Raw materials delivered at mill	1	9¾
Fuel for power (20% of clinker produced), at 6s. 9½d. per ton	1	3½
Fuel for burning (30% of clinker produced), at 7s. 7½d. per ton	2	2¾
Labor (average 36s. per week)	3	0
Repairs, lubricants, etc	2	11½
Superintendence, laboratory and mill office expenses	1	1¾
	12	5¼

A force of 150 men suffice for a 14-kiln plant producing 2,800 tons per week, and of these 118 are unskilled laborers.

For the sake of comparison, the approximate cost of the process at average ordinary English prices for fuel and labor may be computed, taking coal for power at 15s. per ton, coal for burning at 10s. per ton, labor per man per week 24s.

	Cost per ton of cement. s.	d.
Raw materials delivered at mill	1	9¾
Fuel for power (20% of clinker produced) at 15s. per ton	3	0
Fuel for burning (30% of clinker produced) at 10s. per ton	3	0
Labor (average 24s. per week)	2	0
Repairs, lubricants, etc	2	11½
Superintendence, laboratory and mill office expenses	1	1¾
	13	11

These figures may be compared with the cost of production of Portland cement by the older process in the Thames and Medway districts under favorable conditions:

	Cost per ton of cement. s.	d.
Raw materials delivered at mill	1	9
Coal for power (17½%) at 15s. per ton	2	7
Coke for burning (43%) at 15s. per ton	6	7
Labor	4	9
Repairs, lubricants, etc	2	11
Superintendence and expenses	0	8
	19	3

The chief items in which saving is effected are cost of fuel and labor. The amount of fuel for burning is 30% on the weight of the clinker produced as against at least 40% by the old process, and the cost of this fuel is 3s. per ton as against 6s. per ton by the old process. But apart from the question of economy the cement is superior in quality to the product of fixed kilns, and if it had no other merit should appeal to all members of the Institution who are responsible for large undertakings in which concrete is a chief material.

The rotary method as carried out at various American works and at several on the Continent, details of which are in the authors' possession, is a very different thing from the efficient and economical Hurry-Seaman process. In all, the main idea has been to use a rotary kiln and thus obtain a large output per unit of plant and to save labor. But these desirable objects have been very imperfectly attained. In the United States the kilns are generally heated by oil,* which is a convenient and efficient fuel, and readily yields a powerful blast-flame when blown into the kiln by air or steam. Its cost, however, is high, about 3 cts. per gallon, or, say, £1 15s. per ton as against coal at 10s. per ton. The cost with oil burning may be put down at 8s. 6d. per ton of clinker as against 3s. per ton. for coal. In this country of course the use of oil would be still more costly. In no works with which the authors are acquainted is powdered coal being used smoothly and successfully. Several are attempting to employ it, but with mediocre success. The usual and obvious method is to blow the powdered coal in with a fan, a method of feeding which is far less regular than that secured by a properly-contrived injector. In consequence of this the temperature is less controllable, and unburnt fuel may even be driven far up the kiln. As a result much underburnt material is produced, and the lining of the kiln is irregularly heated and occasionally portions are carried away. The clinker thus contaminated is no better than that prepared in the old-fashioned fixed kilns, and of course on account of its small size is impossible to pick. In a few plants producer gas is used instead of coal or oil, thus reverting to the Ransome and the Stokes processes. There is some difficulty in obtaining a sufficiently high temperature with producer gas alone, which, for the economical use, requires the employment of regenerators; also gas from a single producer fluctuates much in quality, and the burner needs constant control. If this difficulty is overcome by the use of a gas-holder fed from several producers the sensible heat of the gas is lost. Water gas would probably work better, but its cost is too high. There is no fuel so economical and manageable as powdered coal, but its use is only practicable with a well-devised burner. The crude plan of blowing in coal dust and air with a fan is only an elementary attempt to solve the problem.

In no plant other than that at the Atlas works with which the authors are acquainted, or of which they have been able to obtain information, is a satisfactory lining in use. The best unprotected lining is certainly magnesia bricks; these require a backing of fire-brick or loam to prevent overheating of the shell; even then the bricks only last a few months, and their cost is excessive. At most works a brick containing a good deal of alumina, similar to that the analysis of which is given on p. 19, is used. This is corroded freely and repairs are numerous and heavy; indeed with these bricks, if the temperature runs up unduly, quantities of slag are formed, pouring out of the kiln and representing so much spoiled lining and cement. Here and there has been a partial recognition of the fact that the ideal lining would be one of cement clinker, but nowhere outside the Atlas works have the conditions been realized necessary for preparing an effective protective coating of clinker. In only one works within the authors' knowledge is a workable process employed for cooling the clinker. Even in this the cooling process is merely a repetition of that used successfully by Mr. Stokes ten years ago, consisting of a rotating iron cylinder having shelves to raise and let fall the clinker, and through which air is allowed to pass. The crushing, watering and cooling the clinker described are practised in the Hurry and Seaman process alone. In most works the white-hot clinker is suffered to fall from the end of the burning cylinder on to the floor, and is then laboriously shoveled into iron barrows, wheeled away and stacked in heaps to allow it to cool sufficiently to be ground. This may take as much as a week. In some cases the shovelling is dispensed with by carrying the hot clinker away by conveyors, but even then rehandling from the cooled heaps is necessary. There appears to have been no attempt made, save in the Hurry-Seaman process, to hydrate the unsaturated lime compounds by the regulated addition of water, thus to prepare a fully-matured cement without aeration.

PLANTS USING WET RAW MATERIALS.—The foregoing remarks apply equally to the rotary process as performed on both wet and dry materials, but there are certain points in the use of the former which merit separate discussion. At the Atlas works dry raw materials alone are employed, and on the occasion of the authors' visit is was considered necessary to examine a typical plant using wet raw materials in order to ascertain what modification might need to be introduced to adapt the rotary system to English requirements having regard to the fact that wet raw materials are commonly used in this country. With this object in view the works of the Bronson Portland Cement Co., at Bronson, Mich., were visited. This is a small works, but well arranged and producing excellent cement. The raw materials are a calcareous marl which is dug from a marsh by a steam shovel worked from a barge; as soon as the marl is dug out the trench fills with water and the barge can proceed. An indurated clay is used as the argillaceous constituent, but can be washed with the marl to form a slurry. The slurry prepared from these materials contains about 40% of water and is in all respects comparable with the slurry made in English works save that its content of lime is lower—a necessity when an ashless fuel is to be used. It is pumped direct into the upper end of a rotary kiln (Fig. 6), and is there dried and burned at a single operation.

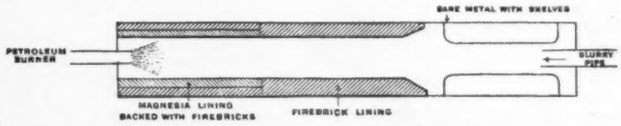


FIG. 6. DIAGRAM SECTION OF KILN FOR BURNING WET MATERIALS USED BY THE BRONSON CEMENT CO.

The upper end of the kiln has no firebrick lining, but is provided with shelves by which the wet slurry is lifted and from which it drops as it proceeds down the kiln. It is well known that slurry, when spread on a drying floor, consolidates into lumps of considerable mechanical strength. If any action of this sort occurred in the rotary kiln it is evident that the lumps would not under ordinary condition of working become fully clinkered, and that, if by lengthening the clinkering zone they were successfully clinkered, they would emerge as large tough hard masses needing crushing before they could be ground, instead of small pieces of uniform size fit to go straight to the grinding mills. To get over the difficulty it would probably be necessary to dry the slurry in a separate cylinder and powder it roughly before introducing it into the kiln proper. Actual examination of a plant working on those materials showed that no difficulty of the kind occurs. The slurry in the act of drying is so broken up by being turned over and lifted and dropped that it forms small nut-like pieces perfectly well-fitted for burning to clinker. As soon as it has reached this condition it proceeds down the kiln and passes through the same steps of decarbonation, dehydration and clinkering which have been described above. At Bronson the kilns are 60 ft. long and 6 ft. in diameter. The temperature of the waste gases is 316° C. The fuel used is petroleum, and no difficulty is experienced in obtaining a high and uniform temperature. The lining trouble is met by the use of magnesia bricks at the clinkering zone. They are effective, but are costly and need a good deal of repairing. There is no attempt to cool the clinker, which is allowed to lie in heaps until cool enough to go to the mills. The output per kiln is 120 tons per week.

Another works using wet raw materials in a rotary kiln is the Hemmoor Portland Cement Fabrik near Hamburg. The slurry, containing about 40% of water, is fed in at the upper end and dries without tending to form large masses. The fuel is powdered coal driven in by a fan. The hot clinker is received in an iron cylinder with internal ribs through which passes air to the burner. No crushing or watering of the clinker is performed. The output of the kiln is 200 tons per week, and the consumption of coal about 30% on the weight of the clinker.

*Since this paper was written, the use of coal dust has extended and that of oil has greatly diminished; the difficulties in the way of employing coal dust, however, still remain.

These two examples of a plant using wet raw materials will serve to introduce the question whether it is necessary for their economical treatment to increase the length of the burning cylinder. The matter is of present importance because extensive works are now being erected in England to handle wet raw materials. It may be noted that a typical kiln burning dry raw materials is 60 ft. long and has an output of 200 tons per week. It this could be worked with the calculated minimum quantity of fuel, viz., 8.23%, the calculated temperature of the waste gases would be 300° C. In practice it is found that as much as 30% of fuel is required, i. e., 72% of the total heat goes to waste. From this it can be computed that the temperature of the waste gases with this consumption of fuel will be 1,085° C. = 1,985° F., and that these gases at this temperature will suffice to dry the slurry necessary to produce 1 ton of clinker, even if it contains as much at 61% of water, assuming that the waste gases have a temperature of 200° C. It must be remembered that a slurry containing 61% of water contains more than twice as much water per unit of dry material as one containing 40% of water, and that the extra quantity of heat needed to evaporate this and provided by the use of 30% of fuel (reckoned on the clinker) is enormous. As shown in preceding paragraphs, the quantity of fuel strictly necessary for drying and burning slurry containing 40% of water is no more than 17.01% reckoned on the clinker. By calculation, supposing the burning and drying to take place in two distinct stages, the temperature of the gases passing from the burning and heating zone to the drying zone is 833.5° C. = 1,532° F.; seeing that the temperature at the clinkering zone will not exceed 1,500° C. = 2,732° F., it is evident that the quantity of heat needed for mere drying is very large. Certain practical deductions follow from these considerations. In the first place it is clear that the burning of dry raw materials under conditions at present obtaining in practice is exceedingly wasteful, and attempts should be made to approach the calculated minimum expenditure of fuel by lengthening the kiln and feeding proportionately faster. It is possible that these experiments might be unsuccessful because the low temperature heat (under 833.5° C.) might not be absorbed with fair efficiency from furnace gases passing through a cylinder of large sectional area. If this temperature were lowered by the admission of more than 100% excess of air (the quantity assumed in the foregoing calculations) the efficiency would drop. Next it may be said that under present conditions, as defined by practice and quite irrespective of theoretical considerations, the proportion of coal needed to burn dry raw materials in clinker, viz., 30%, is the same as that necessary to treat wet raw materials containing 40% of water. Moreover, this quantity of water may be doubled and yet remain within the calculated limits defined by the percentage of coal consumed. Obviously, however, it will be wise to restrict the proportion of water to as low a point as possible, e. g., 35%, because in the event of any irregularity of feed of raw materials or of injection of fuel, a sufficient margin will exist to ensure that the clinker emerges properly burned. Seeing that the raw materials in the act of becoming clinker are enhanced in value about 300%, any

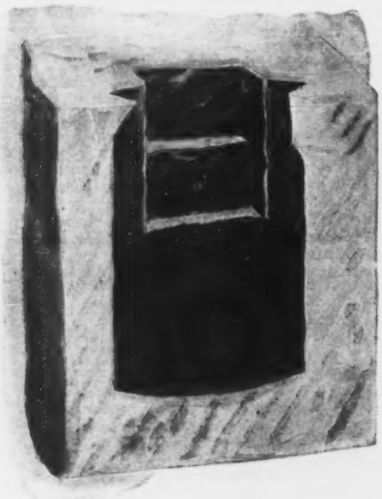


Fig. 2. Sectional View of Hole.

failure in their conversion is a matter of serious commercial importance.

That an additional length of kiln is needed to dry normal raw materials containing 40% of water is obvious. At the end of a 60-ft. kiln the temperature of the exit gases will not be lower than 800° C. when dry raw materials are used. To pick up the heat involved in a drop of temperature from this to 200° C. will need an extension of the kiln, which extension may be as much as one-third its original length. Thus it may be found necessary to construct kilns 85 ft. to 90 ft. long for wet raw materials, if the same output per kiln is to be obtained. Kilns actually in operation on wet raw materials are commonly about 60 ft. long, but their output is below what may be termed the normal output of a kiln using dry raw materials, viz., 120 tons to 150 tons, instead of 200 tons per week. Recently, however, kilns 90 ft. long have been made. The limit to the length of the kiln, given a sufficiently powerful burner, appears to be set only by mechanical considerations. A revolving steel tube with a heavy lining and charge may prove difficult to support satisfactorily when its length approaches 100 ft. and its expansion may be inconveniently great. Probably it will be found that with wet raw materials a length of 20 ft. to 30 ft. additional to that known to be suitable for kilns using dry raw materials will prove economical and effective. Direct experiment is, nevertheless, highly desirable.

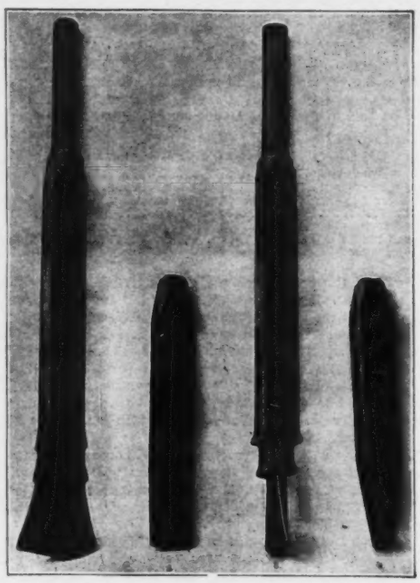


Fig. 1. Drill-Bit and Wedge, Plymouth Power Wedge Hole Cutter.
Ingersoll-Sergeant Drill Co., New York City.

Fig. 3. Transverse Section of Hole.

The result of the author's study of the rotary process set forth in the foregoing pages may be summarized as follows:

(1) The method is so notably superior in economy and in the quality of the product to older processes that it is likely to supersede them in Europe as completely as it has already done in the United States.

(2) That although rotary kilns for the manufacture of cement were originally devised at least 15 years ago, and have been in use more or less successfully since that time, yet it is only within the last few years that a satisfactory system has been worked out in detail. This process is distinguished by the mechanical and continuous handling of the materials from the crushers of raw material to the stock boxes containing finished cement, by the success with which powdered coal (the only practicable fuel in this country) has been applied for heating the kiln, and by the complete solution of the difficulties encountered in preparing a refractory lining. In addition, the process manufactures an artificially-matured cement and thus dispenses with the cumbersome process of aeration by turning over and storage.

(The discussion on the above paper we postpone to our next issue.)

A NEW IDEA IN QUARRYING.

The Ingersoll-Sergeant Drill Co., of New York city, has obtained control of a new quarrying tool for which strong claims are made. The device, known as the Plymouth power wedge hole cutter and wedge, is for the purpose of wedging out dimension stone in manner superior in quality and economy of results to the older methods of plug and feather wedging or Knox blasting. It consists of a specially formed bit used in an ordinary small-size air drill without rotation, and wedges of size to suit the bit. The bit is illustrated in Fig. 1. It has a diamond-shaped lower face and two (sometimes three) sharp-edged side shoulders, all portions tapering back for clearance. The appearance of the hole is well shown in Figs. 2 and 3. The latter view also shows clearly the position of the wedge in the hole. The wedge seats at the projecting angles of the rock, thus concentrating its pressure well below the surface of the rock and avoiding spalling and chipping. The clearance for the tail of the wedge is sufficient at the same time for all driving that may be required.

In using the bit, holes are drilled on the line of the break desired and 9 to 12 ins. apart. The necessary depth of the holes will depend on the nature of the rock, the thickness of the ledge to be broken, etc., but 6 to 8 ins. will usually be found sufficient. A slight inclination, just enough to counteract the natural fracture of the rock, may be given to the hole, and on account of the shallowness of the holes this will cause practically no waste.

A good idea of the holes and their relation to the break may be gathered from Fig. 4, which shows a block 32 ins. thick broken from a ledge of rather wavy sandstone. The surface of fracture is seen to be quite even, in spite of the nature of the rock. The appearance of the shallow holes contrasts strongly with that of a plug and feathered surface, where alternate holes probably would be run down almost the full thickness of the ledge.

In practice the results obtained have been the best. Ledges 48 ins. thick are easily handled, and blocks 2½ ft. wide and 5½ ft. deep have been broken true and square, where hand-cut wedge holes would cause the break to roll off. The time required to drill a hole will depend greatly on the crew, and also on the quality of stone and depth of hole required to give a good break. On an average, the ordinary crew should run 30 to 45 holes per hour, working all day, and 60 or more are often turned out in an hour. The cost of breaking out stone with this system will, of course, be greatly below the cost of ordinary wedging or of blasting with Knox or round holes; but as yet the device has not been used sufficiently to enable accurate cost figures to be obtained.

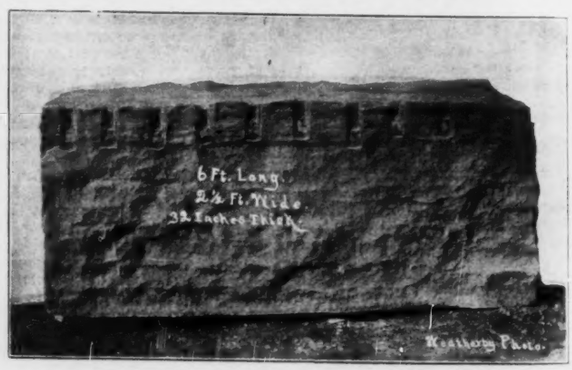
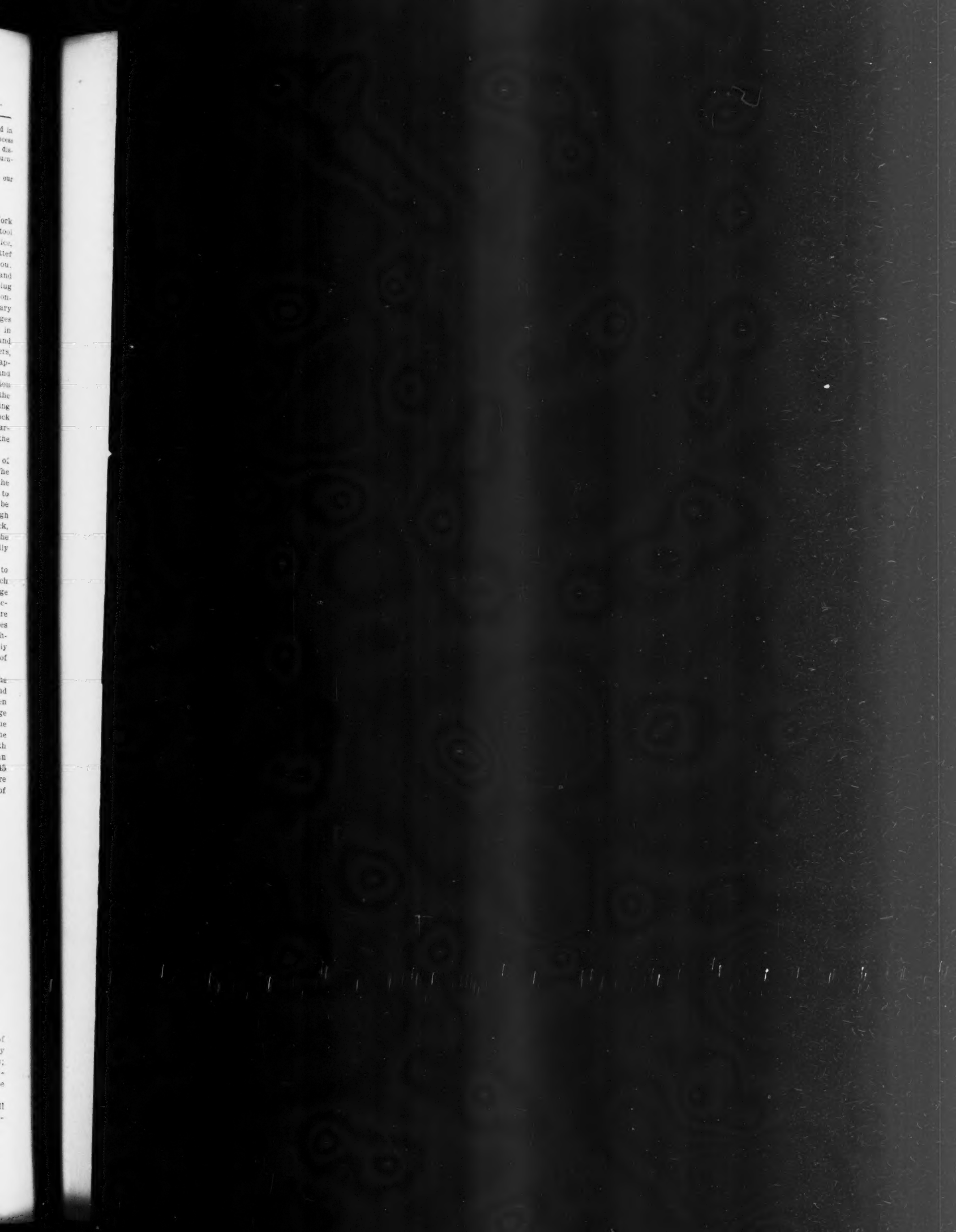


FIG. 4. BREAK IN TOUGH, CURLY SANDSTONE.

We are indebted to the Ingersoll-Sergeant Drill Co. for the illustrations and the information presented.